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ABSTRACT

This yearbook is an effort to reevaluate the metric system and to present testimonies from people in various occupations with respect to metric usage (as of 1948). The first of four major sections explains the metric system and its development. Next are 29 articles discussing the usage of the system in the general areas of education, science, engineering, manufacturing and merchandising, medicine and pharmacy, world trade, armed forces, and athletics. In the public interest section, accounts of magazines, reports, newspapers, radio, and clubs advocating the adoption of the system are given. The fourth section centers on methods of making the adoption both in education and in general. (LS)

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The Metric System of Weights and Measures

THE NATIONAL COUNCIL OF TEACHERS
OF MATHEMATICS: TWENTIETH YEARBOOK

COMPILED BY THE COMMITTEE ON THE
METRIC SYSTEM, J. T. JOHNSON, *Chairman*

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Editor's Preface

THIS is the twentieth in the series of Yearbooks started in 1926 by The National Council of Teachers of Mathematics. The titles of the preceding Yearbooks are as follows:

1. A Survey of Progress in the Past Twenty-Five Years
2. Curriculum Problems in Teaching Mathematics
3. Selected Topics in the Teaching of Mathematics
4. Significant Changes and Trends in the Teaching of Mathematics Throughout the World Since 1910
5. The Teaching of Geometry
6. Mathematics in Modern Life
7. The Teaching of Algebra
8. The Teaching of Mathematics in the Secondary School
9. Relational and Functional Thinking in Mathematics
10. The Teaching of Arithmetic
11. The Place of Mathematics in Modern Education
12. Approximate Computation
13. The Nature of Proof
14. The Training of Mathematics Teachers
15. The Place of Mathematics in Secondary Education
16. Arithmetic in General Education
17. A Source Book of Mathematical Applications
18. Multi-Sensory Aids in the Teaching of Mathematics
19. Surveying Instruments: Their History and Classroom Use

The present Yearbook is a very important addition to the volumes that preceded it and will serve as a companion work to the Nineteenth Yearbook, which deals with surveying instruments. Special emphasis is put on the value of the metric system in all activities involving measurement. It is most illuminating to see in how many fields the metric system is already being used and how many leaders in these fields advocate the general adoption of the metric system in the schools. It seems certain that such adoption would save at least one year of school time for the pupils. Moreover, it seems most important that the metric system be adopted at once while postwar conditions offer an excellent opportunity for the change.

As Editor of the Yearbook series, I wish to express my personal appreciation to Dr. J. T. Johnson and the other members of his committee for their interest and care in seeing the Yearbook through the press.

W. D. REEVE

Foreword

For a long time the metric system has been popular with teachers of mathematics and science, but at the present time, for a number of very good reasons, it seems especially appropriate to review and revalue the metric system with a view to adopting it officially in the United States.

In the present highly scientific and technological age, a system of weights and measures having the simplicity, convenience, and scientific interactions that the metric system possesses can no longer be denied a fair trial.

If we are to achieve that "one world" which offers such hope to a war-tired world, it seems highly desirable to have a world-wide system of weights and measures to go along with the almost universally adopted Hindu-Arabic numerals and musical notation and the widely used Latin alphabet.

At the present time we have millions of Americans who have spent some time in metric countries and have had a considerable amount of experience in using the metric system.

The metric system is taught in practically all classes in high school and college science and to some extent in mathematics classes, and it is used by a large number of commercial firms doing an export and import business or manufacturing products for the almost wholly metric world. If we were to adopt the metric system, we would no longer need to waste the time now spent in teaching the old imperial system of weights and measures and in converting values of the imperial system into their metric equivalents and vice versa.

The implications of accuracy in computing with approximate data make it most urgent that we accept without any further delay a simple decimal system of weights and measures.

This Yearbook represents an effort to re-evaluate the metric system and to present testimonies from people in various occupations with respect to metric usage.

The Yearbook Committee
J. T. JOHNSON
W. D. REEVE
E. W. SCHREIBER
C. N. SHUSTER
L. H. WHITCRAFT

A Note on the Yearbook

The invention of the Hindu-Arabic decimal number system is one of man's outstanding achievements. With it, for the first time in history, masses were able to learn the art of computation. Later Simon Stevin still further simplified the processes of computation by the introduction of the decimal fraction. Today the decimal fraction should be called the common fraction, so widely is it used in commerce and technology.

Still later came the metric system of measures, based upon the units meter, liter, and gram, which are also decimal. To appraise from an inclusive point of view the merits of this system is the purpose of this Yearbook. As an educator and author of textbooks in mathematics, I commend Dr. Johnson and The National Council of Teachers of Mathematics for this publication. If the selection of a system of measures were optional with educators, they would unhesitatingly choose a decimal system. They are well aware of the tremendous effort required to learn, for example, the relationship between the linear units in our system: 1 inch = 1/12 foot, 1 foot = 1/3 yard, 1 yard = 2/11 rod, 1 rod = 1/320 mile. In contrast they appreciate the simplicity and ease with which the pupil could learn: 1 millimeter = 0.1 centimeter, 1 centimeter = 0.01 meter, and 1 meter = 0.001 kilometer.

From the point of view of teaching and learning, it would not be easy to design a more difficult system than the English system. In contrast, it would seem almost impossible to design a system more easily learned than the metric system.

JOHN R. CLARK

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▪ The Metric System of Weights and Measures

1. *System in Measures*

THE NEED FOR CORRELATED UNITS,
THEIR SCIENTIFIC DEVELOPMENT,
AND THEIR WIDESPREAD ADOPTION

The System

The Metric System: What It Is and Why We Need It

C. J. ARNOLD

TODAY we in the United States are faced with a situation that should have our serious attention. We are using two separate systems of measurement for weight, volume, length, and temperature when only one is necessary for any and all purposes. We inherited one, the English system, which grew up in a haphazard way and is now becoming obsolete. The other system, the metric system, the product of mathematical and scientific study, is slowly but surely working its way in. The result of this conflict has been confusion and inefficiency. We now have to learn and teach and use two systems, a necessity which in itself makes our task twice as difficult. We also have to learn equivalents so that we may change units of one system into those of the other; this makes our task of measurement at least four times as difficult as need be.

The solution to this problem, it seems to me, is the elimination of one system, and I hope that you will agree with me after we talk the matter over that it is the English system that should be eliminated. I would like to stress this point: it is a matter of elimination of the English system rather than of adoption of the metric system, because the Congress of the United States adopted the metric system as far back as 1866. One of our leading educators makes this statement: "There is no doubt that if we were starting afresh we would use the metric system. The difficulty arises in the process of making the change from our present system."

Eventually we will make that change; why not now? Why should we wait for the estimated three hundred years or so that it will take for the English system to die out gradually when it could be eliminated in a few years if we made up our minds to do it?

You ask, "Why should it take so long, if the metric system is as good as you say it is?" The answer is the old story of social inertia plus the fact that we as a people are as yet very unscientific.

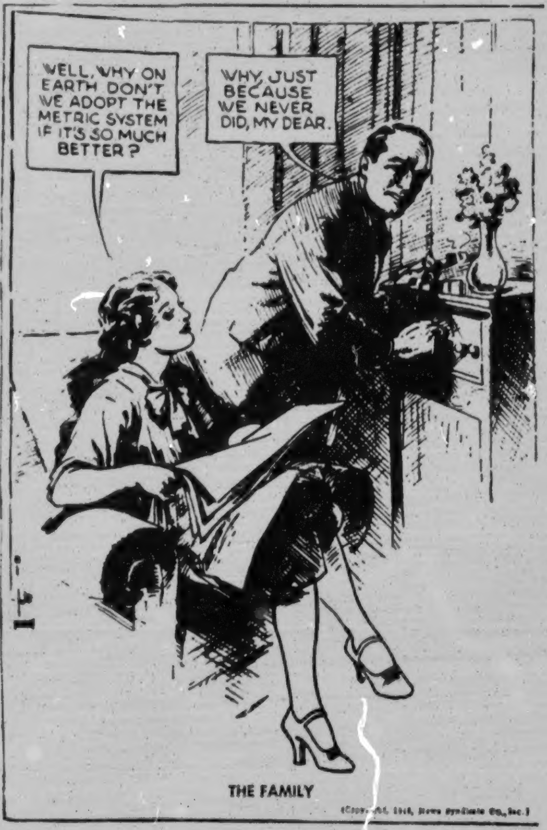
And then you may ask, "Why are you so interested?" Let me assure you first of all that it is not because of the profit motive. No one is paying me a salary to write this article, nor do I anticipate that the Board of Education will increase my salary one iota for my interest and work on this problem.

However, I am interested from several other points of view. First, I am interested as an educator. I began to take the matter seriously last fall when I read an editorial which stated that 20 per cent of the average student's time in school was wasted because of this situation. That to me was shocking inefficiency. The head of the mathematics department of a teachers college stated that two years of elementary arithmetic could be eliminated from the grade school program if the United States would eliminate the English system of measurement. And in checking over the textbooks of the subject which I teach, high school physics, I found, I believe I am safe in saying, that 40 per cent of the work of learning this subject, as now taught, would be eliminated by using exclusively the metric system of measurement. The time saved could be used to good advantage in studying the many new developments in this field. Then, too, mathematics and science are considered by students to be "hard" subjects. They are "hard" because of the mathematics involved, and the mathematics is "hard" because of fractions, and the fractions are there because they are the inevitable result of the use of the English system of measurement. When we discard the English system, we will for all practical purposes have eliminated fractions from education. Under our present elective system of education many students avoid these "hard" subjects. The result is that we are not educating for the modern world—the Age of the Machine—as well as we should. This was well brought out in World War II when the armed forces appealed to the schools to stress mathematics and science and requested them to put in special pre-induction courses in these subjects. We were fortunate indeed to win this war, because we were as unprepared along this line as in many of the others. It is encouraging to note that science is being given major attention in our future plans. In that connection, I believe there is much justification of the indictment of our present system of education by those who say we are still educating for a world that used to be rather than for the world as it is, much less for the world that is to come. The elimination of the English system of measurement, thereby making the subjects of mathematics and science less "hard," would do much to correct this situation.

I am also interested in this problem of standardized measurements from the point of view of a citizen, because the same simplification and increased efficiency that would occur in education would be carried over into every phase of living. There are many other reasons, but space does not permit their discussion here.

I am interested in this problem as a scientist. The metric system is a scientific system and is used in practically all scientific work. Our scientists started out using the English system but soon found it to be altogether too cumbersome and inadequate and were happy indeed to discard it.

Now, since most research is carried out in the metric system, the continued use of the English system stands as a barrier to the ready assimilation of scientific knowledge by the people. The full use of the metric system would speed up the assimilation of scientific facts and prevent or shorten the lag between the discovery and the application of those facts. Consider the housewife—one of her big jobs is to feed her family properly. Since practically all research in nutrition, food, health, vitamins, and so on, is expressed in the metric system, she is forced to get the new findings secondhand. They must first be translated into her old units of measurement. How much more meaningful it would be to her if she could talk the same language of measurement and be able to visualize the true meanings of such terms as *calories, centigrade, grams, milligrams, cc's, liters,* and so forth. Then she would be able to read intelligently the results of such research and keep up with the latest developments and discoveries. And what is true


WELL, WHY ON EARTH DON'T WE ADOPT THE METRIC SYSTEM IF IT'S SO MUCH BETTER?
WHY, JUST BECAUSE WE NEVER DID, MY DEAR.
THE FAMILY

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of the housewife is true of the farmer, the butcher, the baker, the candlestick maker, and everyone all the way down the line. The full use of the metric system would go a long way in removing the "mystery" that now seems to surround science for so many people and makes it seem a world apart.

And finally, after study of this problem I am impressed by its similarity to many other problems confronting our civilization, so that the solution to this problem, as I see it, may well serve as a model for many others. Space does not allow going into this.

However, I would like to point out several important things in passing.

First of all, as a people we are very immature scientifically, and we have by no manner of means reached the ultimate in civilization. It has often perplexed me to understand how we as a people could so readily accept some of the products of science and still be so reluctant to accept science itself. That reluctance is due, as I see it, to our past history and bringing up. Scientific progress consists of two phases: first the discovery of truth, and second the assimilation of truth into our civilization. The discovery of truth is no good to man unless he assimilates it into his civilization. Much has been said recently about social progress lagging behind scientific progress. This, however, is not the case, because scientific progress covers all real progress. What has happened is this: science has made more rapid progress in certain fields than in others. In those fields where scientific facts could be readily assimilated we have had rapid progress, but in those fields where facts had to displace ideas already held by peoples the rate of progress has been considerably slowed.

This brings me to the second point that I wish to emphasize. Frederick the Great made a very significant statement: "The greatest pleasure which men can have in this world is to discover new truths, and the next is to shake off old prejudices." I would stress that the biggest job confronting the world today is the shaking off of old prejudices and that this undertaking should provide man with his greatest pleasure. Few of us will be able to experience the pleasure of discovering a new truth, but we can all participate in the process of casting off old prejudices. I believe that science has already revealed enough of these new truths so that if they could be assimilated into our present civilization we would have today a peace and prosperity far greater than our fondest dreams. The situation is similar in the case of the metric system. It is here, *now*, but we cannot realize its many advantages simply because we have not seen fit to cast off an old way of doing things. That is why I consider this problem of standardizing measurements to be largely a problem in elimination of the old measures.

I said we were scientifically immature. Let's see why. In this respect we are still savages. The savage has many taboos, and the man who defies them pays the penalty. Similarly we in civilized societies bind our minds with prejudices. We form powerful groups and organizations to protect and perpetuate these prejudices. We fasten them to a shred of truth, perhaps, and wrap them up with our emotions—even with life and death itself, so that we are willing to shed our blood, to wage war if necessary, to hold on to those prejudices. What chance has new truth against such a system?—very little. We take the innocent and unsuspecting individual at birth and pour him full of our preconceived ideas and prejudices under family and social pressure until he becomes, and probably will remain forever, warped in outlook. No child is ever born with prejudices—he has to acquire them.

That brings me to the third point. Prejudice, by and large, is resistance to change. One fact that science has clearly established is that we live in a world of change—a dynamic, progressive world of change. Nature will not tolerate for long our prejudices, our resistances to change. She will have her way. That is why the history of so-called civilized man has been a story of conflict and war and must continue to be so until man learns to shake off his prejudices. And that is why science, which arrived in the last few seconds of man's history, comparatively speaking, has become *man's first great hope on earth.* Science provides him with the means of testing and proving his ideas to determine whether they are true or not. Now if he will only use it, war and conflict will be a thing of the past. Man does not fight over established and proved truth. Thus the responsibility is placed directly on man himself—and the big job right now is to cast off prejudice.

Have you ever been concerned about the next war and the probability of its destroying our present civilization? Have you ever thought of putting that question to Nature? She would answer, I am sure, "Present civilization must go—it isn't good enough for future generations—and either you must destroy it through rapid change and by giving up your man-made prejudices, or I will destroy it as I have always done in the past. And," continues Nature, "I would remind you that, in some ways, wars have been good for you. They have served as steppingstones in your progress. But now you have a new tool—science. Use it, eliminate your prejudices, and build a new civilization of peace and prosperity." In the words of John Dewey, "The future of our civilization depends upon the widening spread and the deepening hold of the scientific habit of mind."

There has been an interesting connection between war and the development and spread of the metric system. It was in 1790 following the Revolution in France that the metric system got its start. For this reason it is sometimes called the French system. Following the Prussian War, in 1871, when Germany, Austria, and Hungary made the metric system mandatory, the population using the metric system was doubled. The population using the metric system doubled again at the close of World War I, 1920-1921, when Russia, China, Japan, and Turkey made its use mandatory for their people. Today 75 per cent of the world's population uses the metric system, and fifty-five out of fifty-seven so-called civilized states in the world use it. That leaves only two not using it, and who do you suppose those two are? They are the world's two great democratic groups, the British Empire and the United States. That should give us some concern about "democracies," but space does not permit discussing that, either.

The metric system is nothing more or less than the application of the decimal number system to measurements. Science and mathematics go hand in hand. Mathematics is one of the most important tools of science; so let's take a look at the history of mathematics to get a little background. It is said that the use of mathematics is one of the measures of a civilization. The savage could count and measure. Later man could do simple computations. If he had six rows of corn with seven hills in a row, he could say 6 times 7 equals 42 instead of having to count each hill to find the total. Now let's work a simple problem in computation as we would have done it five or six hundred years ago. Let's add:

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DCCCCLXXXXVIIII
  CC XX    V
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  MCC   X  X IIII
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How would you like to work problems by this method today? You would not like it; yet that is probably the way you would be doing them if it had not been for another war. The Romans, like us, were pretty well satisfied with their civilization. Then about A.D. 1500 the Hindu-Arabic system superseded the Roman system. As a result we work the above problem today in this manner:

$$\begin{array}{r} 999 \\ \underline{225} \\ 1224 \end{array}$$

You say there is a big difference. Yes. But I want to say that there will be a bigger difference in our method of working problems when we have made full use of measurement units decimally related than there was after the change to the Hindu-Arabic numeral system from the Roman numeral system!

The Hindu-Arabic system is a "tens" system, the value of any digit in a whole number varying with its place in the number, starting with units at the right and increasing to the left in the order: units, tens, hundreds, thousands, and so on. Each place value is ten times the place value to its right; thus 999 means 900 plus 90 plus 9.

The Arabs also brought the Romans a method of dealing with parts of a whole—fractions. They had learned about fractions from the Egyptians, who were believed to have developed them in 1600 B.C. As a result, the Romans became able to work with mixed numbers—a whole number and a fraction, such as 999 3/4.

Then in 1585 Simon Stevin, a Flemish mathematician, made one of the greatest inventions of all time. In man's history it will rank with the invention of the wheel and the discovery of fire. He took an ordinary dot (.), moved it to the right of a number, and made a decimal point of it. Without that decimal point I doubt whether we could have won World War II, for without it we could not have done much of our higher mathematics, such as logarithms, calculus, and the like. Einstein could not have developed the equation for the transformation of matter into energy, without which we could not have developed the atomic bomb, nor could Clerk-Maxwell have predicted the radio wave fifteen years before it was actually discovered and made the basis for present-day radar.

The decimal point extended the "tens" system to the right as well as to the left. It made it possible to decrease by tens as well as to increase by tens. Moreover, it made it possible to handle a whole number and a part as easily as a whole number was handled before. It also provided for a great increase in the fineness of measurements. But most important of all as far as we are concerned here is the fact that it made the use of fractions for most purposes obsolete. However, since we have been thinking in terms of fractions for some 3,500 years, it will be necessary for us to make a conscientious effort to get rid of them if they are to disappear in actual practice.

The metric system, being based on the decimal system, starts out with a basic unit. The next larger unit is ten times as large, the next smaller unit one-tenth as large, and so on. As a matter of fact, we can begin with any unit in the system and this same relationship holds.

To illustrate further, let's take an example of our present use of the decimal system, the United States monetary system, and contrast it with a fractions monetary system, that used by the British. We can make change with comparative ease, whereas the Briton has to memorize a rhyme in order to make change. Our prices are listed as one number, such as $1.98, but the Briton has to go to the trouble of stating the number of pounds, shillings, pence, and so on, separately. If we were asked to change back to the English monetary system, we would have none of it; we would consider it a step backward, as it would be. In this connection, I would call to your attention the fact that no country having once adopted the metric system has ever returned to its former system.

The same simplicity that we find in our decimal monetary system is found in the metric system of measurements for weight, length, volume, and temperature. Let's show this by working two simple problems, side by side, in the two systems. Our problems will call for converting smaller units to larger ones.

161 centimeters = 16.1 decimeters = 1.61 meters
161 inches = 13 5/12 feet = 4 17/36 yards

In the metric system the conversion is simply a matter of shifting the decimal point one place to the left to get the next larger unit.

But in the English system to change inches to feet it is necessary to divide by 12, and since I cannot readily do this in my mind, I must set it down as a division problem and work it out. Right away I am involved in fractions. To change feet to yards I must divide by 3, a small enough number, but again I run into difficulties because I have to divide a mixed number, that is, a whole number and a fraction.

Let us work a problem in figuring costs, starting with corresponding units and determining the cost for smaller units.

If 1 metric ton costs	$160,000.00	But if 1 long ton costs	$160,000.00
then 1 kilogram costs	$160.00	then 1 pound costs	$71.43
and 1 gram costs	$.16	and 1 ounce costs	$4.46

Since a metric ton contains 1,000 kilograms, all I need to do is shift the decimal point three places to the left to get the cost per kilogram; and since there are 1,000 grams in 1 kilogram, I again shift the decimal point three more places to the left, and I have the cost per gram. Contrast this with the work involved when English units are used. One long ton contains 2,240 pounds, and I am forced to work a problem in long division to find the cost per pound, with the chance that it will never come out integrally. To change pounds to ounces I am again forced to work a long division problem to find my cost.

If you consider the English system of money stupid, what must you think of the English system of measurement? Let me ask you a question: Which is heavier, a pound of feathers or a pound of gold? You will probably reason that gold seems heavier but that since a pound is a pound, they must weigh the same. But you are wrong. The pound of feathers is heavier. In fact, it would take about 4 pounds of gold to equal the weight of 3 pounds of feathers. You see, there are two kinds of pounds, the avoirdupois and the troy. Yes, and there are two kinds of quarts, dry and liquid, and fifty-six kinds of bushels, which vary from state to state and also according to commodity—apples 50 pounds to the bushel, wheat 60, oats 32, rye 56, and so on. An official United States bushel contains 2,150.42 cubic inches but for tariff purposes becomes a "heaped" bushel of 2,747.715 cubic inches, an increase in size of 27.8 per cent; yet in Connecticut it is 2,564 cubic inches, whereas Michigan says it "shall be heaped as high as may be without special efforts or design." There are nine different kinds of barrels, eight kinds of tons, and so on. In fact, the U.S. National Bureau of Standards uses over five hundred pages of fine type to do the job of defining all the units. Yes, it is both ridiculous and stupid. But you people are responsible—not for starting it, of course, but for permitting it to continue.

Now let us take a problem in computing volume. It will show nicely the contrast between a fractions system and a decimal system. I am taking this problem from an article of mine which was published in the March, 1946, issue of the *Minnesota Journal of Education* entitled "Let's Eliminate Fractions."[1] Here we can compare the space area used in working two equivalent problems: finding the volume of the same tank as measured by the two systems. Here is the problem in English measurements: Find the volume in cubic feet of a tank 4 feet 9 7/16 inches long, 2 feet 3 5/32 inches wide, and 1 foot 11 3/4 inches deep. In metric measurements the problem is: Find the volume in cubic meters of a tank 145.89 centimeters long, 68.98 centimeters wide, and 60.33 centimeters deep. The solution of the English problem requires a working area of nine times the area required by the metric problem. Moreover, the solution of the English problem involves two separate operations of long division as well as the difficult operation of multiplying a fraction times a fraction times a fraction. The solution of the metric problem involves only straight multiplication of three decimal numbers. Then, too, consider the time involved—a clock would be needed to time an American child in working this problem, while a Russian child, for example, in working this same problem his way would have to be timed with a stop watch.

In the drug business it is often necessary to increase or decrease a formula, as, for example: Increase six times the formula 6 pounds 11 ounces 137 1/2 grains. The answer is 40 pounds 3 ounces 387 1/2 grains. The solution requires forty-eight figures, not including abbreviations. In the metric system a similar problem would be: Increase six times the formula 6 kilograms 977 grams. The answer is 41 kilograms 862 grams. Only ten figures are required. However, in actual practice metric measurements are usually stated in one unit. Expressed in this way, our original formula would read 6.977 kilograms. In this case only three figures are required to increase the formula, in contrast with the forty-eight required in the case of the English measurements. The results of using the metric system are a great saving in time and a great decrease in the possibilities of making errors. These advantages mean greater efficiency.

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[1] See page 149.

One factory which switched to metric measurement estimated that in one year it saved ten times the cost of new measuring devices. A railroad company estimates that the metric system would save $50,000 a year in paper work alone. During World War II the weight of a sack of flour was changed from 48 to 50 pounds and the weight of a barrel of flour from 192 to 200 pounds. Such a simplification as merely rounding out a number resulted in the saving of much time and money, as all concerned will testify. All benefited—the producer, the shipper, the merchant, the consumer, and the government. It was much easier to make out bills of lading, to figure daily production and costs, to make out statistical reports, and to carry on all the other processes where figures and mathematical computation were involved. If results like these follow so simple a change, what would be the effect if we went all the way and changed to the metric system for all purposes and uses? Truly it would be revolutionary, increasing our efficiency in all walks of life.

The metric system, in addition to its simplicity and its decimalization of units, provides a one-to-one correspondence between weight and measure. It is in reality one all-inclusive system, whereas English measurements consist of separate, unrelated systems for weight, length, and volume. For example, 1 cubic centimeter of water weighs 1 gram, whereas 1 cubic foot of water weighs 62.4 pounds. The result of the correlations within the metric system is that when we find the volume of water in metric units, we also have the weight. If the volume is 10 cubic meters, the weight is 10 metric tons. This is far from the case in the English system. If the latter is used, seventy-one figures and a knowledge of multiplication of mixed numbers are required to find the weight of a tank filled with water when the tank measures 4 feet by 3 feet 6 inches by 2 feet 4 inches. It takes only twenty-one figures and no knowledge of the rather intricate multiplication of mixed numbers to find the weight of water in a tank 4 meters by 3.6 meters by 2.4 meters.

I believe that in a few years it will be possible to enact the necessary federal legislation to adopt the metric system and that in the meantime an extensive program should be set up to build a strong public opinion in favor of the elimination of the English system. Now, what about it? Are you willing to help eliminate the obsolete English system in the next five years or so, or do you prefer to let the present state of confusion and inefficiency drag on for another three hundred years? Are you willing to condemn your children and your children's children to waste a great deal of their time and energy in school, and then have them turned out as handicapped persons—persons who can't think in decimals—persons who are ill equipped for scientific work and thinking—persons who are not even qualified for simple jobs in those industries now using the decimal metric system? This is your responsibility. What are you going to do about it? It is time for action.

Weights and Measures Through the Ages

JOSÉ ORTIZ MONASTERIO

EVERY day and in many ways we poor mortals are led to believe that we have advanced on the road of civilization.

We are familiar today with a great number of contrivances which would, no doubt, bewilder, perplex, confound, and shame the men of days gone by; but, in the midst of our triumph, we have to humble ourselves when we realize that we are, in some very important aspects of our daily lives, as badly off as the descendants of Noah.

If we go back and read the eleventh chapter of Genesis, we find the story of the building of the famous tower of Babel, erected by the men of those days who were the descendants of Noah. According to this chapter of Genesis, mankind, which in those days constituted a single, united body and possessed the same language, came, in wandering around, to a beautiful valley in the land of Shinar. Men felt, as we do today, that they had made wonderful advances in the art of construction, and they devised a plan to use, for the first time in the history of mankind, baked bricks as building material and bitumen as a mortar. They represented, in fact, the first city builders. Unfortunately, they were also fired with the ambition of erecting a tower so high as to reach heaven, a hyperbolic expression which means that they were possessed by arrogance and pride. And on that occasion, as always happens when men get drunk with pride and imagine that they are higher than others, Jehovah decided to check their ambitious designs. He brought about a confusion of tongues so that those working together in the erection of the tower could no longer understand each other; and as a result of this they were dispersed over the face of the globe.

Since that day men have had difficulty in understanding one another, because of the diversity of languages. As a consequence of this curse men, when they found out in their daily life that they had to establish units of measurement in order to be able to transact all kinds of business, began to establish units or standards, which naturally varied from one country to the next, thus adding to the existing confusion of the languages.

The diversity of units of measurement, which, as in the case of language, was the natural result of the conditions of existence of the different peoples, had at least one encouraging element: several units were based on parts of the human body. Notwithstanding this fact, there was a difference between these units, because the foot of the Egyptians measured 26 centimeters, while that of the Chaldeans and Assyrians was a little longer, 324 millimeters. The Persian foot was 32 centimeters, but the Greek was 296 millimeters and, finally, the Roman foot was 295.7 millimeters.

At the fall of the Roman Empire metrology was generally based on the system of measures of the Romans, but later new ones were introduced in the different European kingdoms, with the result that commercial intercourse among these countries was made difficult.

Charlemagne was one of the first to try, during the eighth century, by the Capitulary of Aix-la-Chapelle, to unify the units of measure. Charles I of France, "the Bald," by his decree of Pistes, commanded that all units of measure in his kingdom should be adjusted to the standards deposited at his palace, but he did not succeed, because the nobility, especially the poor country squires, found it an advantage to continue deriving a revenue from the inspection and marking of measures. Later, Philip IV, "the Fair," and Philip V, "the Tall," tried in vain to correct the confusion existing in France with the units of measurement in use, which in fact were different from one province to the next and even from one town to the other. In the year 1540 Francis I and in 1575 Henry III tried again, but without success. Not until the seventeenth century was France able to unify, for the first time, her system of weights and measures, following the ideas of the Abbé Mouton.

I have selected the foregoing brief review of metrology in France because it is typical of what was going on in the other leading nations of modern times and also because we owe to France the only real serious and scientific approach to a simple and unified system of weights and measurements.

In his system of measures Abbé Gabriel Mouton selected as a national unit of length the minute of 1° of arc, and he gave to this unit the name of *milliare* and subdivided it by a decimal system into the centuria, decuria, virga, virgula, decima, centesima and millesima. Unfortunately the Abbé died without having seen his ideas adopted; nevertheless his ideas on metrology were, in principle, adopted later on.

Following this attempt were the attempts of the English architect Wren, of the French astronomer Picard, and of Huygens, who decided to use as the unit of length the one corresponding to the seconds pendulum.

In the year 1790 the great Talleyrand had a law passed by the National Assembly for the unification in France of the system of weights and measurements. A committee of the Academy of Sciences was entrusted with this work, and the members decided to use the ten-millionth part of the fourth of the earth's meridian as the unit of length. Thus the *metre*, or meter, came into existence as the base of a scientific, simple, and decimal system of weights and measures.

The new system was finally adopted by France on April 7, 1795 (18 Germinal, An. III). Notwithstanding the eventual absolute success of the metric system, it is well worthy of note that at first its progress was slow. Belgium, Luxemburg, and Holland were the next countries to adopt it, and by the end of the nineteenth century it had become the standard of forty nations and had attained world-wide use in science.

It is bewildering that the United States and the British Empire, two leaders in manufacturing and exporting, still cling to their unscientific, antiquated system of weights and measures. In favor of the use of the metric system all over the United States, we have the highly authoritative opinion of Samuel W. Stratton, formerly Director of the Bureau of Standards, who writes: "Commerce, technology, and science have, on account of their international character, availed themselves of the advantages of the metric system more than manufacturing, which is local, and, unlike exporting, not in direct touch with world markets. Hence, science and commerce, with their world-wide outlook, should be the advisers of industry, and their conclusion is that the first principle is to supply what the customer needs, and that international business requires international weights and measures."

As to the way scientists in England feel about this matter, we have the following emphatic opinion from the late Lord Kelvin: "I believe I am not overstating the truth when I say that half the time occupied by clerks and draughtsmen in engineers' and surveyors' offices—I am sure at least one-half of it—is work entailed upon them by the inconvenience of the present farrago of weights and measures. The introduction of the world Metrical System will produce an enormous saving in business offices of all kinds—engineering, commercial and retail shops." [1]

Furthermore, when in the year 1895 a deputation advocating the introduction of the metric system into England consulted the opinion of Arthur J. Balfour, he used the following words: "Upon the merits of the case I think there can be no doubt whatever that the judgment of the whole civilized world, not excluding countries which still adhere to the antiquated systems under which we suffer, has long decided that the metric system is the only rational system."[2]

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[1] Quoted with permission from *World Metric Standardization*, by Aubrey Drury and others (World Metric Standardization Council, San Francisco, 1922), p. 442.

It is indeed hard to understand, after learning of the opinions of the leaders, how the United States and the British Empire still hold fast to their antiquated, unscientific, irrational hodgepodge of weights and measures, when the rest of the civilized world is already enjoying the advantages of the metric system! It looks to me like another case of pride and arrogance similar to the one which brought upon humanity the curse of the confusion of languages. Today, in the era of air navigation which has brought us a few hours' time from the remotest points of the globe and, as a consequence, is bringing together the men of all latitudes, it would be a most fitting contribution to the cause of good understanding among men, if the great English-speaking nations of the British Empire and the United States would make compulsory the use of the metric system in their commercial intercourse with the rest of the world and within their own boundaries.

Is All This *Really* Necessary?*

CHANNING POLLOCK

A FRIEND in London once confided in me that he had never spent a holiday on the Continent because "they drive on the wrong side of the street." Not "on the right side, while we drive on the left," mind you, but "on the *wrong* side." I've often related this as an illustration of instinctive intolerance, but it's even more an instance of how firmly our habits become fixed, and how much we are troubled by the need of setting them aside.

As a matter of fact, I wonder why old dogs must forever be learning new tricks? Every time one crosses a border in Europe, or, to some degree, in the United States, there are strange currencies, customs, languages, weights, and measures, and what not, which partly explain why the people with whom they are regulation continue to seem strangers. Few Americans really speak

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[2] *Ibid.*, p. 461.

* Reprinted from *The Rotarian* for April, 1946, with permission of the publisher and of the author.

English, and fewer Englishmen speak American—both actually as many different tongues as there are localities—but all of us understand one another, and that's the chief reason for the bond between the two nations. A man belongs to your lodge when you use the same high-sign, and everybody has a weakness for members of his own lodge.

Homo sapiens, who isn't always so sapient, doesn't want to be bothered or confused, and Heaven knows there's been plenty of bother and confusion when he began mixing with "foreigners." Take money, for example—and most of us are willing to take as much of it as we can get. But even a seasoned old traveler like myself can go haywire trying to recall how many cents make a penny, and whether drachmas or taels make sense.

I shall never forget my first arrival in Hong Kong—from Java. The porters refused to accept any of the various currencies in my pockets, so I carried the lot to a money-changer near the hotel, who calculated with an abacus, or bunch of wooden balls sliding on wires, and I shall never know how I happened to get what I got for my coin collection. Neither shall I ever know what it was worth on the home grounds. Anyway, it wasn't worth much when we entered the next Province, because every Province has its own currency and snoots the other fellows'. In my opinion, the Chinese are the most nearly civilized people on earth, and why they must have as many kinds of money as Americans have accents completely baffles *me*.

Not that, in any area of comparable size, Europe is better off. You can't travel overnight from Paris in any direction without beginning the next day by exchanging your bank roll. Mostly, value is fixed by the decimal system—or, rather, in recent years, it hasn't been fixed at all.

When the American Express in Athens begged me to pay my bill in Italy, where money was more stable, I thought, "Thank Heaven, the American dollar is always a dollar"—and found it wasn't before I reached Florence, because, meanwhile, America had gone off the gold standard. All *that*, of course, is a question apart, and it's about to be answered, we're told, by agreements in Bretton Woods, or the Black Forest, or somewhere. What's eatin' me is why there shouldn't be some sort of a coin or bill that can be expended as easily in London or Bangkok as in New York. Why was it ever necessary for the average visitor in England to go about reciting, "Twelve pence make a shilling, and 20 shillings a pound, unless it's a guinea, and then it's 21, but what in heck is half a crown"?

Weights and measures are a little less varied because, in 1799, delegates from almost everywhere got together in Paris and adopted the metric system. From almost everywhere, that is, except Britain and the United States, which cling to different versions of the imperial system, thus complicating life a little bit more. The metric system has been legalized both in Britain and in the United States, but, as it isn't commonly used in either country, that doesn't seem to make much difference.

Don't ask any Englishman or American what the metric system *is*, and, if you begin reading about it, and discover it to be based on the fact that the meter, its unit, is intended to be one ten-millionth part of the earth's meridian quadrant, and is so very nearly, you'll probably stop right there. Most of us do know that the metric system is a decimal system, and ten meters are a decameter and 1,000 a kilometer, or ten liters a decaliter, and a hundredth of a liter a centiliter, and that's all to the good, but something snaps when you try to translate on the basis that a yard is .91440 meters, a troy ounce 31.1035 grams, and a fluid ounce 2.95625 centiliters. That sort of figuring, I believe, is what turned Professor Einstein's hair white. At any rate, you *can* say, "One thousand meters are a kilometer," rather than having to remember that 12 inches are a foot, 3 feet a yard, and 1,760 yards a mile. How many square feet are in an acre, no one but surveyors has ever known, and only druggists and liquor dealers try to recall how many gills or fluid ounces are in a pint.

After all, most of this needn't trouble most of us very much, but, when you have to begin translating quarts into liters or miles into kilometers—well, as my grandmother used to say, that's a gray horse of another color. The answer to so commonplace a question as "How far is it to the next village?" becomes an exercise in mental arithmetic for any Englishman or American. Of course, if you can remember it—or even if you can't—a kilometer is approximately five-eighths of a mile, but that only makes it more difficult. The signpost informs you, "Brussels—326 1/2 kilometers." QUICK; how many miles is that? Einstein, or Joel Kupperman, of the Quiz Kids, might reply promptly, "204.0625 miles," but it's dollars to doughnuts *you* can't. Ninety-nine out of 100 wandering Englishmen or Americans simply divide the number of kilometers by two and add one-fourth of the result—i.e., 100 kilometers are 50 miles plus one-fourth of 50, 12 1/2, or 62 1/2 miles—but even that distracts your attention from driving, and I have had friends—particularly woman friends—who got results not a bit like those I have given. My own spouse, who is everything to me but a lightning calculator, once assured me that it was almost exactly 4,000 miles from Cherbourg to Paris, though neither she nor I ever discovered how it got that way. At any rate, wouldn't it be simpler and easier to measure distance by miles everywhere, or, better still, to use the metric system in England and America as well as in the rest of the civilized world?

Failing this, the wife aforesaid suggests that a kilometer be made precisely half a mile, and a stone 10 pounds, instead of 14, which puts it beyond her mathematical powers. Frankly, I don't think either device would work, or that we could induce the British to take ten pence for a shilling and ten shillings for a pound. No; universal systems would be a lot more practical. Until they are adopted, I, for one, shall never know whether it's hot or cold at 70 degrees Centigrade. The fact that the freezing point of water is 32 degrees Fahrenheit, and the boiling point 212, while they are zero and 100 Centigrade, means nothing in my young life, and never has. Once in Cambodia, after I'd said 20 times, "I can't stand this heat," I found the mercury at 50 Centigrade, and stopped perspiring. One rule for reducing Centigrade temperature to Fahrenheit is: subtract 10, subtract from the remainder one-tenth of itself, double the last remainder, and add 50 to the product. Is this a procedure to appeal to a man who merely wants to know whether he's comfortable? I ask you!

If you've ever attempted piloting a motorcar through the busy streets of London, you realize it's equally difficult, when you suddenly meet another car rounding a corner, to remember that you must pass it on the left. A morning of this gives one sympathetic understanding of my friend who declined holidays on the Continent, where, as with Americans, you drive on the right side of the highway. There are a dozen explanations of this difference in custom, most of them based on the idea that a man wanted his sword arm free, but the need of swords in the street went out so long before the automobile came in that you might as well eat your food raw because once we didn't know how to make fire. In America, the legend runs, people got in the habit of turning right because so many people traveled on horseback and by keeping to the right of the road, the right hand was free to draw a weapon. In Britain, however, the driver of a six-in-hand coach rode a horse on the left side in order to have full scope in swinging his whip. This is probably poppycock, and we drive on the right or left merely because our ancestors preferred one or the other, and we lacked the initiative to choose which *we* prefer. Just as the streets in Boston are said to follow the original cowpaths.

The same thing is true of writing, spelling, and speech. One group of ancestors made one set of sounds and another group another set, and we went on with it. At least 1,000 different languages are spoken in this world, and each of them with variations and additions of argot. Small tribes of savages, often numbering only a few hundred individuals, cannot understand other and equally small tribes in villages a few miles apart. The Swiss use four different tongues in their one tiny nation, and when I lived there in 1890, all shop and street signs in Prague were printed in German *and* Czech. As my father was, a man may be the master of ten languages, and yet visit a dozen lands where he can ask for a boiled egg only by crowing like a rooster. I have a certain amount of sympathy for an unlettered friend of mine who used to get very angry because the Parisians couldn't understand English spoken with what she believed to be a French accent. Certainly, it does not reflect credit on our civilization that, after centuries of mixing, one population is practically without means of communicating with the others.

Admittedly, the answer isn't easy. Scholars have invented many "universal languages"—chiefly Esperanto—without inducing more than a few hundreds or thousands of people to acquire them. Efforts to make English universal, allegedly because it is the mother tongue of nearly 200 million, but really, I suppose, because it's *our* mother tongue, have got nowhere. French is called "the language of diplomats," but there have always been plenty of statesmen who didn't know a word of it. Perhaps in time, now that we have about conquered distance, and peoples co-mingle as never before, we shall develop a tongue that is a mixture of all tongues, and can be spoken by all peoples, but don't bet on it. You probably *would* be safe in wagering that such a development would go a long way toward universal understanding and friendship.

Anyway, there seems little doubt that many of the bothersome differences in money and measurements and suchlike are due to be eliminated. Generally, I'm agin standardization. I shall never forget my disappointment that I could take a trolley car to the pyramids of Giza, and that, when I got there, I was only in another kind of Coney Island. I've never considered a vacation in the United States, because fruit cup is the same in San Francisco that it is in New York, and equally inevitable in both places and all points between. I should, or shall greatly dislike a world in which all people and places are pretty much the same, and you have to call up the stationmaster to learn whether you're in Canton, China, or Canton, Ohio. Nevertheless, it does seem to me stupid, and opposed to general amity, that I can't say, "Good morning," to a brother outside of two or three nations without an interpreter, or find exactly how much beer I've drunk on an afternoon in Amsterdam without multiplying by 4.5459631.

Development

The Early History of the Metric System

EDWIN W. SCHREIBER

It was down in old Mexico that I had my first *real* introduction to the metric system. 'Tis true I had met the *meter* and her children, *centimeter, millimeter,* and little *micron,* in a formal way while busy in the laboratories at the university in my undergraduate days—but that was a cold and scientific acquaintance. Under a warm southern sky, with the sun doing its full share to brighten the picture, I read in no uncertain letters on a freshly painted sign which was posted on a little railway station in old Sonora: "To Calexico, 33.5 Km." So here upon a common road (not a royal one) *kilometer* and I met face to face. From that friendly meeting with a member of the metric system a desire was kindled within me to know more about the family history of the meter, and since that time I have picked up some interesting facts covering the whole family, some of which it is my purpose to relate at this time.

Mother Earth is the mother of the meter. The French scientists who devised this unit of measurement at the close of the eighteenth century planned that it should not be dependent upon any particular measuring stick of human construction but instead should bear a definite relation to the dimensions of our globe. The art of measuring the earth and determining its shape, known as geodesy, had already made much progress, and no other people had contributed so much to it as the French. It was not strange, therefore, that the authors of the metric system should decide to take as the basis of this system a meridian of the earth—a circle passing through both poles. For greater exactness (since meridians are not all of precisely the same length) they selected a particular part of a particular meridian. They decided that a meter should be the *ten-millionth part of the distance from the North Pole to the equator measured on the meridian passing through Paris.*

In considering the genesis of the modern metric system as a universal system founded on an invariable standard and symmetrically and conveniently developed, it is necessary to go back to Gabriel Mouton (1618-1694), Vicar of St. Paul's Church, Lyons, who first proposed in 1670 a comprehensive decimal system having as a basis the length of an arc of 1′ of a great circle of the earth. One minute of arc would give the length of a *milliare*, which would be subdivided decimally into *centuria, decuria, virga, virgula, decima, centesima, millesima.* The *virga* and *virgula* would be the chief units of the system corresponding to the *toise* and the *foot* then in use. This geometric foot (*virgula geometrica*) was further defined by Mouton as corresponding to the length of a pendulum making 3,959.2 vibrations in a half hour at

Lyons. This proposition contained essentially the germ of the modern metric system, and Mouton's suggestion of the pendulum was soon repeated by Jean Picard (1620-1682) in 1671, and by Christian Huygens (1629-1695) in 1673.

During the eighteenth century several schemes were proposed by scientists for the improvement of the weights and measures, but although they were brought to the attention of the French Government, they did not meet with such approval as to secure their adoption. These various schemes were discussed and discarded without any definite action, and, just as in later times, the difficulties attending the introduction of a new system were anticipated and feared. In fact, Jacques Necker (1732-1804), in a report made to Louis XVI in 1778, spoke of the proposed reform of weights and measures with considerable diffidence. He wrote:

> I have occupied myself in examining the means which might be employed to render the weights and measures uniform throughout the Kingdom, but I doubt yet whether the unity which would result would be proportionate to the difficulties of all kinds which this operation would entail on account of the changing of values which would necessarily be made in a multitude of contracts, of yearly payments, of feudal rights and other acts of all kinds. I have not yet renounced the project, and I have seen with satisfaction that the Assembly of Haute-Guyenne have taken it into consideration. It is in effect a kind of amelioration which can be undertaken partially, and the example of a happy success in one province would essentially influence opinion.

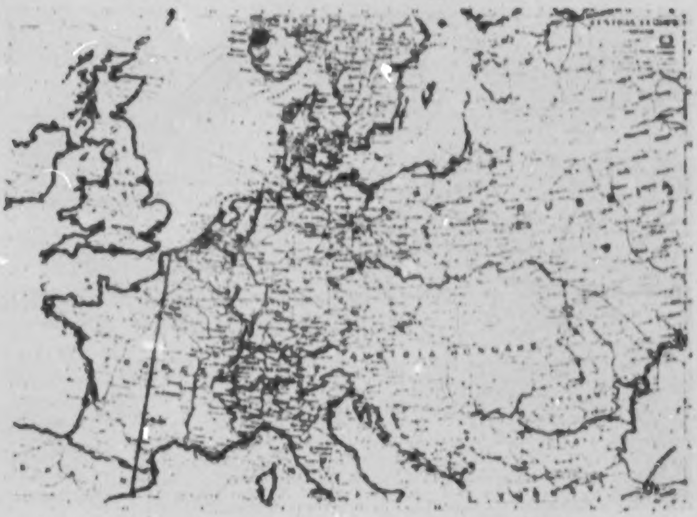
Let us turn back the pages of history to 1878 and discern this same note of diffidence in the following statement by J. E. Hilgard, Assistant, United States Coast Survey, and Inspector, United States Standard Weights and Measures, who in response to a resolution by the House of Representatives submitted a report dated March 21, 1878, on the obligatory use of the metric system for government business:

> Not only are lands purchased from the public domain described in a simple decimal system of acres measured by square chains and decimals, but all the most valuable real estate, such as lots and streets in cities, has been laid off in this country in even feet, generally even tens of feet, as 50, 60, 80, 100, 150, etc. What adequate motive is there to change these expressions into terms which are necessarily fractional and in which those foreign nations whose convenience it is proposed

to meet have no conceivable interest? What useful purpose is subserved by designating a building lot 24 by 120 feet in the form of 7.315 by 36.576 meters? It is the foregoing and similar considerations which lead the undersigned to doubt whether the international units of measures will ever wholly take the place of all others in our domestic transactions.

With the changes wrought by the French Revolution it was possible to gain consideration from the public for rational ideas in science as well as in government and religion. It was Talleyrand (1754-1838), a bold and able leader, then Bishop of Autun, who brought a plan for reform to the attention of the National Assembly in April, 1790. He appreciated not only the necessity of a uniform system of weights and measures for France but also the desirability of a system that would be truly international rather than represent merely the weights and measures of Paris. Through the efforts of Talleyrand the National Assembly rendered a decree on May 8, 1790, which was sanctioned by Louis XVI on August 22 of the same year. The decree read in part as follows:

> The National Assembly, desiring that all France shall forever enjoy all the advantages which will result from uniformity of weights and measures, and wishing that the relation of the old measures to the new should be clearly determined and easily understood, decrees that His Majesty shall be asked to give orders to the administrators of the different departments of the Kingdom, to the end that they procure and cause to be remitted to each of the municipalities comprised in each department and that they send to Paris to be remitted to the Secretary of the Academy of Sciences a perfectly exact model of the different weights and elementary measures which are in usage.
>
> It is decreed further that the King shall also beg His Majesty of Britain to request the English Parliament to concur with the National Assembly in the determination of a natural unit of measures and weights; and in consequence, under the auspices of the two nations, the commissioners of the Academy of Sciences of Paris shall unite with an equal number of members chosen by the Royal Society of London, in a place which shall be respectively decided as most convenient, to determine at the latitude of 45°, or any other latitude which may be preferred, the length of the pendulum (seconds), and to deduce an invariable standard for all the measures and all the weights; and that after this operation is made with all the necessary solemnity, His Majesty will be asked to charge the Academy of Sciences to fix with pre-



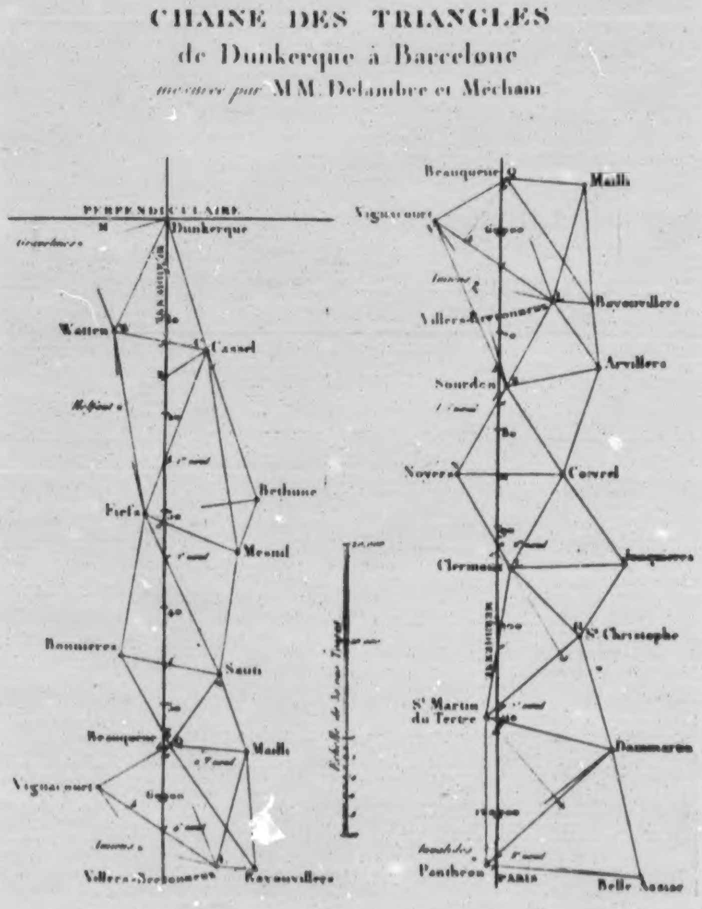
The black line shows the meridian from Dunkerque to Barcelona.

cision for each royal municipality the relation of the old weights and measures to the new standard, and to compose afterward for the use of the municipalities the usual books and elementary treatises which will indicate with clearness all these propositions.

It is decreed further that these elementary books shall be sent at the same time to all the municipalities to be distributed; at the same time there shall be sent to each of the municipalities a certain number of new weights and measures which they shall distribute gratuitously to those who would be caused great expense by this change; and finally, six months only after the distribution, the old measures shall be abolished and replaced by the new.

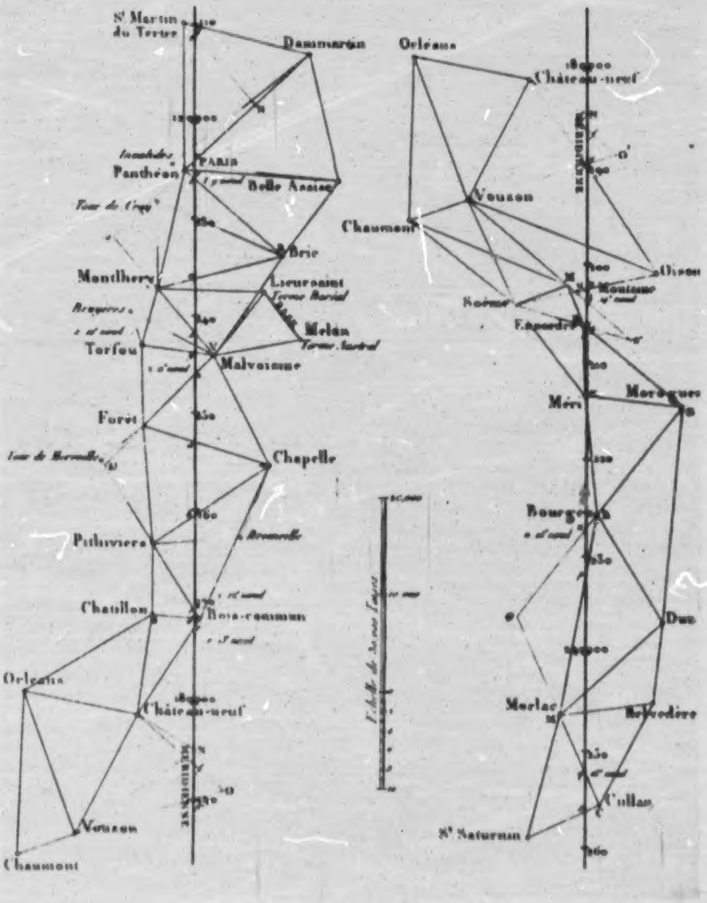
Finally, the Academy shall indicate the scale of division which it believes most convenient for all weights, measures and coins.

A committee of the Academy, consisting of Borda, Lagrange, Laplace, Monge, and Condorcet, presented a report on March 19, 1791, to the effect that after an arc (of meridian) had been measured, the length of a quadrant could then be computed, and one ten-millionth of its length could be taken as the base or fundamental unit of length. The plan proposed was to measure an arc of meridian between Dunkerque on the northern coast of France, and Barcelona on the Mediterranean Sea. These two places were


CHAINE DES TRIANGLES
de Dunkerque à Barcelone
mesurée par MM. Delambre et Méchain
PERPENDICULAIRE
Dunkerque
Watten
Cassel
Bethune
Fiefs
Mesnil
Bonnieres
Sauty
Beauquesne
Mailly
Vignacourt
Villers-Bretonneux
Bayonvillers
Sourdon
Noyers
Coivrel
Clermont
Jonquieres
St Christophe
St Martin du Tertre
Dammartin
Pantheon
PARIS
Belle Assise
MERIDIENNE
Echelle de 20 000 Toises

The chain of triangles from Dunkerque to Paris, a distance of 151 miles.

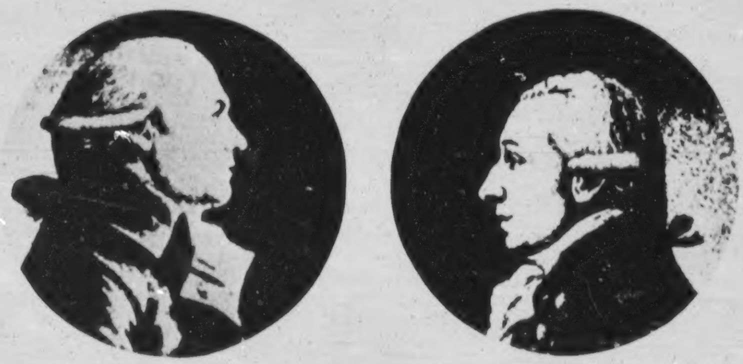
chosen because they were situated at sea level in the same meridian; because they offered a suitable intervening distance of about 9° 30′, the greatest available in Europe for a meridian measurement; because the country so traversed had in part been surveyed previously by Lacaille and Cassini in 1739-1740; and furthermore because such an arc extended on both sides of latitude 45°.


St Martin du Tertre
Dammartin
Orléans
Château-neuf
Inv...
Panthéon
PARIS
Belle Assise
Vouzon
Chaumont
Brie
Montlhery
Lieursaint
Torfou
Melun
Malvoisine
Forêt
Chapelle
Pithiviers
Chatillon
Bois-commun
Orléans
Château-neuf
MERIDIENNE
Vouzon
Chaumont
Oison
Soême
Moutiers
Epaudry
Méri
Morogues
Bourges
Dun
Morlac
Belvedère
Culan
St Saturnin

The chain of triangles, continued. The base at Melun measured 6,075.9 toises or 7.359 miles.

On May 29, 1793, in the report of the committee to the National Academy the name *metre* (meter) was assigned to the *ten-millionth part of the quadrant of the earth's meridian.* The *provisional* meter was devised from a calculation of the operations made by Lacaille in 1740. A standard of the provisional meter made of brass was duly constructed by Lenoir in Paris and is preserved in the Conservatoire des Arts et Metiers at Paris. This provisional meter varied from the meter finally determined by the commission in 1799 by only 1/3 millimeter, being that much too long.

The King of France, on June 10, 1792, issued a proclamation in which Delambre and Méchain, the two engineers chosen to survey the arc between Dunkerque and Barcelona, were commended to the good offices of government officials and citizens generally, and various rights and privileges were secured to them. Both scientists straightway proceeded to their duties, but, owing to the turbulent revolutionary conditions in the country, they encountered from the beginning constant embarrassment and difficulties. In addition to being arrested and deprived of ordinary facilities to carry on their work, they met with little sympathy and cooperation on the part of officials and people and experienced great difficulty in erecting and maintaining their signals, which were oftentimes believed to have been built for military purposes.



Left. Jean Baptiste Joseph Delambre (1749-1822). *Right.* Pierre François André Méchain (1744-1804).

Méchain in Spain had a certain amount of assistance from the government of that country, but here, as in southern France, he was harassed and interfered with by political troubles. In fact, these two resolute engineers experienced almost incredible difficulties, being arrested by the various governing bodies that were at that time successively administering the affairs of France, deprived of liberty and freedom, prevented from working by accident and disease, and, in short, accomplishing most creditable results under remarkably adverse circumstances. Finally, in November, 1798, Méchain and Delambre completed their survey and brought their records to Paris. Several committees were set to work checking results and compiling reports. On June 22, 1799, a platinum meter was adopted as the true meter and was deposited in the Archives of the State, where it has come to be known as the Meter of the Archives. Thus, we see, it took seven long and arduous years to make the first standard meter stick. The units of mass and capacity were constructed along with the meter, but there is not space for a detailed account of the evolution of these standards.

After the scientific determination of the standards, there remained to effect the general adoption of the new weights and measures. This was a much more difficult task than was at first contemplated. After more than a third of a century of confusion and chatter among people of all estates with regard to the metric system the government was forced to act with determination, and the act which follows, in part, was passed, after much discussion, by the Chamber of Peers and the Chamber of Deputies and was announced to the people on July 4, 1837. It decreed the general use of the metric system for all measurements.

> After January 1, 1840, all weights and measures, other than the weights and measures established by the laws of 1795 and 1800, constituting the decimal metric system, shall be forbidden under the penalties provided by article 470 of the Penal Code. Those possessing weights and measures, other than the weights and measures above recognized, in their warehouses, shops, workshops, places of business, or in their markets, fairs, or emporiums, shall be punished in the same manner as those who use them, according to article 479 of the Penal Code. Beginning at the same date all denominations of weights and measures other than those authorized are forbidden in public acts, documents, and announcements. They are likewise forbidden in acts under private seals, commercial accounts, and other private legal documents, etc.

In response to an invitation of the French Government, the following countries sent representatives to a conference held in Paris on August 8, 1870, to consider the advisability of constructing new metric standards:

Austria
Colombia
Ecuador
France
Great Britain
Greece
Italy
Norway
Peru
Portugal
Russia
Spain
Switzerland
Turkey
United States

A second conference was held two years later, at which thirty countries were represented, the United States again being among this number. At this conference it was decided that new meters and new kilograms should be constructed to conform with the original standards of the Archives, and a permanent committee was appointed to carry out this decision. The preparation of the new standards had advanced so far by 1875 that the permanent committee appointed by the conference of 1872 requested the French Government to call a diplomatic conference at Paris to consider whether the means and appliances for the final verification of the new meters and kilograms should be provided, with a view to permanence, or whether the work should be regarded as a temporary operation.

In compliance with this request a conference was held in March, 1875, at which nineteen countries were represented, the United States as usual being of this number.

On May 20, 1875, seventeen of the nineteen countries represented signed a convention which provided for the establishment and maintenance of a permanent International Bureau of Weights and Measures to be situated near Paris and to be under the control of an international committee elected by the conference, the committee to consist of fourteen members, all belonging to different countries.

In addition to the primary work of verifying the new metric standards the International Bureau was charged with certain duties, the following being the most important:

1. The custody and preservation, when completed, of the international prototypes and auxiliary instruments.

2. The future periodic comparison of the several national standards with the international prototypes.

3. The comparison of metric standards with standards of other countries.

The expenses of the International Bureau were to be defrayed by contributions of the contracting governments, the amount for each country depending upon the population and upon the extent to which the metric system was in use in the particular country.

In accordance with the terms of the convention, the French Government set aside a plot of ground in the park of Saint-Cloud just outside of Paris, and upon this ground, which was declared neutral territory, the International Bureau of Weights and Measures was established.

The construction of the meters and kilograms had been entrusted to a special committee, and early in 1887 the committee completed its work and the new meters and kilograms were turned over to the International Bureau for comparison with the standards of the Archives and with one another.

It had been decided as early as 1873 that the new standards should be made of an alloy of 90 per cent platinum and 10 per cent iridium. All together, thirty-one meters and forty kilograms were constructed. By 1889 the entire work was completed, and in September of that year a general conference held at Paris approved the work of the international committee.

The meter and kilogram which agreed most closely with the meter and kilogram of the Archives were declared to be the international meter and the international kilogram. These two standards, with certain other meters and kilograms, were deposited in a subterranean vault under one of the buildings of the International Bureau, where they are accessible only when three independent officials with different keys are present. The other standards were distributed by lot to the various governments contributing to the support of the International Bureau.

In closing, let us follow the journey of these fundamental standards from the Old World to the New. B. A. Gould, official delegate from the United States to the International Conference of Weights and Measures held at Paris in September, 1889, accepted the standards from the International Bureau. He had them packed and sealed and then transferred to the care of Whitelaw

Reid, the United States Minister in Paris. From him Meter No. 27 and Kilogram No. 20, together with Meter No. 12 of the alloy of 1874, were received by George Davidson, Assistant in the United States Coast and Geodetic Survey, by whom they were brought to Washington with great care and deposited in the Office of Weights and Measures. On January 2, 1890, Meter No. 27 and Kilogram No. 20 were carried to the Cabinet room in the Executive Mansion, where the ceremony of breaking the seals upon the boxes was performed in the presence of the President of the United States, Benjamin Harrison, the Secretary of State, James G. Blaine, and the Secretary of the Treasury, William Windon, together with a distinguished company of scientific men. A formal certificate declaring the condition of these standards at the opening of the boxes was signed by the President and witnessed by the Secretary of State and the Secretary of the Treasury. A somewhat similar certificate was signed by the other gentlemen present. In consequence of this official act of the President of the United States, Meter No. 27 and Kilogram No. 20 will be guarded as our National Prototype Meter and Kilogram. These national standards are at present kept in a subterranean vault of the National Bureau of Standards in Washington.

Strange as it may seem, the standard of length in the United States is not the yard, as is popularly believed. In 1893, by act of Congress, the meter was made the United States standard of length and the yard was defined as 3,600/3,937 meter.

Later Trends in Metric Usage

JOSEPH J. URBANCEK

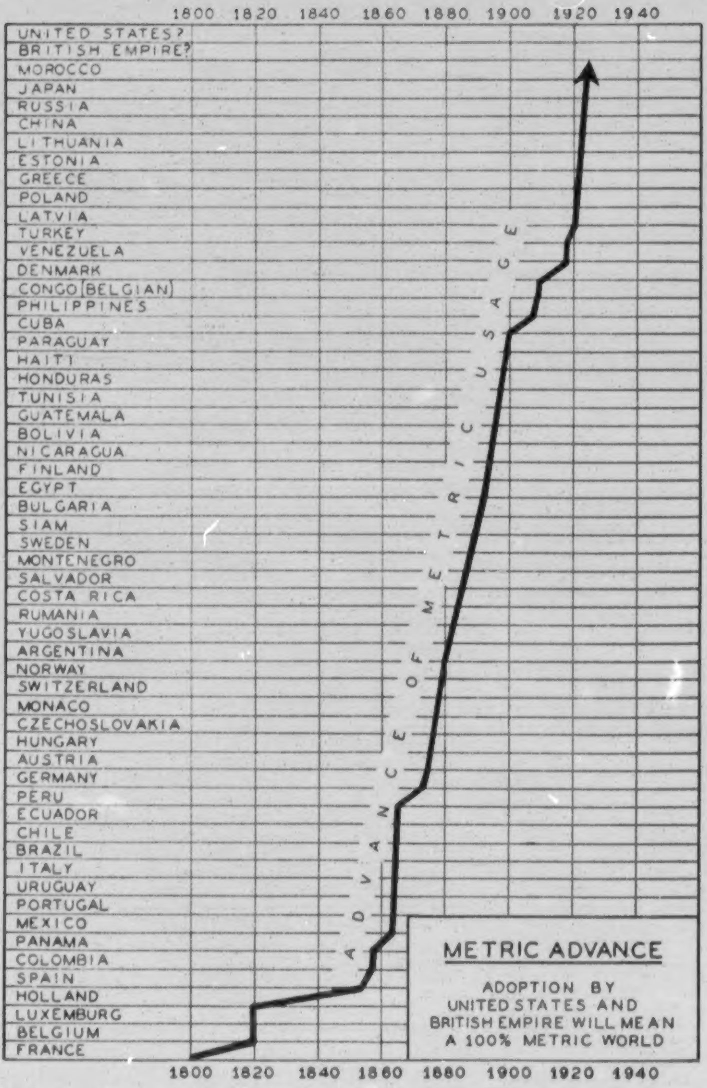
SINCE the adoption of the metric system by France, the merits of the conveniently workable relationships between length, capacity, and weight have attracted an ever-increasing number of nations and people. The countries which have adopted the metric system and the year of adoption are shown in the accompanying graph.

A study of the graph reveals slow initial progress. Nearly a generation passed, following the official establishment of the French meter in 1799, before the near neighbors of France adopted the system. In the forty-year period between 1860 and 1900 the advance was quite rapid, and from 1900 to 1925 it continued at about the same rate. Since 1925 nearly one-quarter of a century has passed, but the British Empire and the United States are still unmoved by the procession of national adoptions. Within the period from 1820 to 1925, fifty-two nations, over 80 per cent of the population of the world, changed over to the general use of metric weights and measures. At the present time more than 1,200,000,000 people live where the legal use of the metric system of weights and measures is mandatory.

Although the British Empire has not yet officially adopted the metric system of weights and measures, progress has not been at a standstill. In 1862 a British parliamentary committee held extended hearings on the subject of metric standardization and unanimously recommended that the British Isles adopt the metric system. Despite the esteem felt for the new system and the favorable attitude toward it, it received little more than academic attention. Decades passed before scientific and other interested groups succeeded in having the system legalized in 1897. In 1900 ninety-six members of Parliament were in favor of a metric bill. A short time later the British House of Commons voted to adopt the metric system exclusively, but the House of Lords rejected it. In 1904 the House of Lords passed a similar bill, but through political maneuvering the House of Commons killed it by the close vote of 150 to 126. By 1906 those voting in Parliament for a metric bill increased to 414, and by 1907 interest in such a measure had further increased, so that the bill, when called for passage, lacked but a few votes of passing.

Meanwhile, other parts of the Empire were giving expression to their wishes. The House of Representatives in Australia endorsed the reform for decimal weights and measures by a vote of thirty-six to two. The governments of Canada, South Africa, and New Zealand have taken an active part in the reform by declaring themselves strongly in favor of it. Activity and agitation for the official adoption of the new type of measures has continued.

Some critics point out that the British Isles, in their conservatism, have lagged too far behind, that they still retain the old


1800 1820 1840 1860 1880 1900 1920 1940
UNITED STATES?
BRITISH EMPIRE?
MOROCCO
JAPAN
RUSSIA
CHINA
LITHUANIA
ESTONIA
GREECE
POLAND
LATVIA
TURKEY
VENEZUELA
DENMARK
CONGO (BELGIAN)
PHILIPPINES
CUBA
PARAGUAY
HAITI
HONDURAS
TUNISIA
GUATEMALA
BOLIVIA
NICARAGUA
FINLAND
EGYPT
BULGARIA
SIAM
SWEDEN
MONTENEGRO
SALVADOR
COSTA RICA
RUMANIA
YUGOSLAVIA
ARGENTINA
NORWAY
SWITZERLAND
MONACO
CZECHOSLOVAKIA
HUNGARY
AUSTRIA
GERMANY
PERU
ECUADOR
CHILE
BRAZIL
ITALY
URUGUAY
PORTUGAL
MEXICO
PANAMA
COLOMBIA
SPAIN
HOLLAND
LUXEMBURG
BELGIUM
FRANCE
ADVANCE OF METRIC USAGE
METRIC ADVANCE
ADOPTION BY UNITED STATES AND BRITISH EMPIRE WILL MEAN A 100% METRIC WORLD
1800 1820 1840 1860 1880 1900 1920 1940

undecimalized pounds, shillings, pence, and farthings of an antiquated and discarded German coinage. New ideas do not often receive ready acceptance. When George Stephenson made application to the British Parliament to run the first steam railway in the world, he met much resistance. To show his folly the opposition asked, "What would happen if a cow got in the way of your engine?" To the ultraconservative mind there could be only one answer: the overturning of the train and the destruction of life and property. Shocking was the effect when Stephenson calmly replied, "It would be bad for the cow." Thus a new idea was born. On another occasion a prominent English lord said, "We don't want foreign things even though better. We have all the best of it—we can understand the metric units, but foreigners absolutely cannot understand ours. We've got 'em!" On still another occasion in the British Parliament, Lady Astor said, "Many British legislators are still in Noah's Ark." While the conservative attitude may be strong in some of their people, the British also have their quota of progressive-minded citizens who have taken an active part in the metric standards movement.

It is important to note that the business and commercial interests of the British Empire have frequently declared their opinions. One of their later meetings resulted in definite action. The Ninth Congress of the Chambers of Commerce of the British Empire, held in Toronto in 1920, adopted resolutions overwhelmingly in favor of a gradual adoption of the system of decimal metric weights and measures throughout all the Empire. Through their activities during World War I, millions of Britons had actual experience with metric units and were impressed by their simplicity and efficiency. This caused a concerted movement to arouse the British Parliament to activity on the issue. The resolutions cited above merely reflected the sentiment of the time. Thousands of petitions poured in to the British Prime Minister, to the British Board of Trade, and to the committees on coinage, weights, and measures of the houses of Parliament. It is estimated that in the years from 1914 to 1922 more than 100,000 petitions were received by Parliament.

Decimal associations of the British Isles coordinated their efforts with the World Standardization Council and the American

Metric Association. The British Decimal Association in London, in conjunction with the World Metric Standardization Council and the World Trade Club, published in 1920 a comprehensive British edition of the booklet, *Who Urges Meter-Liter-Gram?* This British Decimal Association has published hundreds of useful leaflets, pamphlets, booklets, and reports. In addition it published for years a most valuable magazine called *The Decimal Educator.* The Association's collaborators, both numerous and eminent in British life, were drawn from thousands of concerns, organizations, and individuals.

By the time the decade of 1920-1929 was reached, the metric advance was urged by colonial conferences, colonial parliaments, chambers of commerce, trade unions and councils, county councils and town councils, educational authorities, scientific societies, professional organizations, agricultural associations, manufacturers' associations, trade associations, thousands of commercial and industrial concerns, the National Union of Teachers, the Incorporated Society of Inspectors of Weights and Measures, and influential individuals.

The reader may wonder why it was not an easy matter to pass the necessary legislation in view of such a prodigious effort put forth in favor of it. Two or three major factors worked against its passage. Some manufacturers opposed it because of the mistaken notion that it would be necessary to scrap their machinery. Competitors in other countries, jealous of their own advantages in world markets, helped to finance campaigns against the adoption of the necessary legislation in the British Empire and the United States. Numerous other reasons can be found in the literature, but the chief difficulty in the British Empire undoubtedly can be attributed to faulty coordination between the various legislative and executive departments of the government. At several periods of British history, concerted action would have carried the metric units into exclusive use as the sole legal standards. Following the 1920's, however, other problems beset the Britons, and interest in the new system of weights and measures lagged; therefore the British Empire is today deprived of the efficiency that would be provided by the metric system as the only legal system of measurement in business transactions.

The progress of metric measurement in the United States has many parallels with that in the British Empire. According to the Constitution of the United States, only Congress has authority to fix and establish weights and measures. Most people of this large and (in many ways) most progressive nation would like to see Congress exercise that right in adopting the decimal metric system for all activities, commercial, industrial, educational, scientific, professional, and non-professional.

The decimal system in the United States has a long history, extending from the very beginnings of our republic to the present time. Thomas Jefferson's re-entrance into the Continental Congress in November, 1783, was most fortunate, because our decimal coinage system, without exaggeration the most perfect the world has ever known, was established through his efforts. The successful introduction of this system was all the more remarkable because it was necessary to replace the arbitrary pounds, shillings, and pence to which the populace had been accustomed as British subjects. Against the stolid force of British habits, Jefferson stood all his life for a still broader reform; he wished to have the decimal system applied to all the weights and measures as well as to money. Had he drawn up a declaration of independence against the tyranny of obsolete and unfair weights and measures brought over from Britain at an earlier period, he would surely have had the signatures of George Washington, John Adams, Benjamin Franklin, James Madison, Gouverneur Morris, Alexander Hamilton, John Hancock, Charles Carroll of Carrollton, and other founders of the Republic, for they all worked to that end. The details and numerous problems of launching the new government doubtless lessened action on securing uniformity of weights and measures at this time.

Had the United States of America, then a very young nation, been invited along with the European nations to participate in the world conference on weights and measures in France in 1790, she might have secured metric standardization at the outset, as France did.

In his message to the First Congress of the United States of America, George Washington on January 8, 1790, made the following statement in regard to the standardization of measures:

> A uniformity of weights and measures is among the important objects submitted to you by the constitution, and if it can be derived from a standard at once invariable and universal, it must be no less honorable to the public council than conducive to the public convenience.

Although Congress did not adopt world metric standardization, it did proclaim the superiority of the decimal system.

In 1799, the year in which France adopted the metric system, the United States was engaged in a "quasi war" with France, and this no doubt deterred us from adopting metric standardization at that time. Observant Americans, however, were constantly aware of the advantages of standardization. Congress discussed it, and in his annual message of 1816, President James Madison urged decimalized uniformity of weights and measures. John Quincy Adams, Secretary of State, in his *Report on Weights and Measures*, in 1821, foresaw world metric standardization. The topic seldom failed of attention, and in 1847-1848 the Secretary of the Treasury and the Superintendent of Weights and Measures urged world uniformity on the basis of the decimal system. In 1861, Salmon P. Chase, Secretary of the Treasury, pleaded that Congress act promptly in adopting international standards. Then came the Civil War, and of necessity interest turned to other things.

On March 8, 1864, an exceptionally fine report by the British parliamentary committee of 1862 on the world advance of metric standardization was laid before Congress. Abraham Lincoln was interested in this report, since he regarded metric standardization as an essential measure of reconstruction. It was undoubtedly in accordance with his views that metric legislation was introduced into both houses of Congress. As a result and on the first recommendation of a committee of Congress, headed by John A. Kasson, which submitted an elaborate report, Congress passed the following act on July 28, 1866:

> An Act to authorize the use of the Metric System of Weights and Measures.
>
> Be it enacted by the Senate and the House of Representatives of the United States in Congress assembled, that from and after the passage of this act it shall be lawful throughout the United States of America to employ the weights and measures of the metric system, and no con-

tract or dealings, or pleadings in any court, shall be deemed invalid or liable to objection because the weights or measures expressed or referred to therein are weights or measures of the metric system.

Probably at no previous time was there more discussion of metric standardization in this country or more general acceptance of metric units as exclusive standards throughout the world. Since 1866 Congressional committees on weights and measures which have reported on the subject have urged legislation for the adoption of meter-liter-gram standardization.

The next step was taken in 1876, when coinage was put on the metric basis. It had been decimalized nearly a century before. The new plan established the weight of a coin and its ratio to other coins. A dollar weighed 25 grams, a 50-cent piece 12.5 grams, and other silver coins proportionately. Coins made of other metals were also metricized.

The Navy Department adopted the metric system exclusively for its medical work in 1878. By 1894 the War Department had taken the same step. That same year the metric system was adopted for all electrical work. The U. S. Bureau of the Public Health Service joined the growing number of users in 1902. Meanwhile the new measuring technique was legalized for continued use in the Philippine Islands in 1909, and in 1913 it was recognized and permanently established in Puerto Rico. When World War I was under way, our Expeditionary Force by the hundreds of thousands used the metric system. This no doubt had much to do with the bringing before Congress, in 1924, of the Britten-Ladd Metric Bill. More will be said about the activity of that time in later paragraphs.

In addition to adopting the metric system in the instances cited above, the United States belongs to the International Bureau of Weights and Measures, the custodian of the world standard meter and kilogram; to the International Postal Union, the rates of which are based on the gram; and to the International Institute of Agriculture, which gives crop quotations in metric tons. Furthermore, the United States employs metric measures in International Air Service Regulations; in the Coast and Geodetic Survey; in the governmental agencies of the U. S. Geological Survey, the U. S. Lake Survey (War Department), the Mississippi River Commission (War Department), the Tennessee Valley Authority, and the U. S. Hydrographic Office; in the National Bureau of Standards; and in the Bureau of Chemistry.

Metric weights and measures are used exclusively in some fields and almost so in others. Persons familiar with the related areas of science know of the esteem held for, and the use made of, scientific metric measurement in such fields as chemistry, physics, and dietetics. Many hospitals and factories throughout the country have already adopted the system and in many cases have used it for years. The American jewelry trade in 1913 adopted the metric carat of 200 milligrams and practically overnight began its use. In the following year similar action was taken in Great Britain. The optical industry has found the metric system most useful because lenses can be ground to the same standard no matter in what country the prescription originated. The international Olympic Games athletic events are now measured, and results are published, in metric units. Radio wave lengths are measured and recorded in meters and other metric units. At a conference in 1926 of the International Air Traffic Association, an international air consignment note for freight was adopted which required the use of metric weights and measures. A new waybill was introduced to conform to the adoption. It seems apparent that metric usage is ever on the increase and that sooner or later (and preferably sooner) the British Empire and the United States should take the final step to use of the metric system exclusively for all weights and measurements.

Following World War I activity reached a peak on behalf of exclusive use in this country of the metric system of weights and measures in all transactions, both national and international. Individuals, associations, educators, clubwomen, bankers, editors, manufacturers, businessmen, professional men and women, congressmen, and legislators by the thousands were actively supporting the movement. Publications, periodicals, pamphlets, newspaper articles, and editorials by the hundreds were appearing in support of the same project. Only a glimpse into the extent of these activities can be afforded here.

The World Metric Standardization Council (San Francisco), in cooperation with the American Metric Association (New York) and the British Decimal Association (London) and other organizations did an immense amount of work in providing publicity and in attempting to coordinate effort. Much aid came from national organizations such as the American Association for the Advancement of Science, the American Chemical Society, the National Wholesale Grocers Association, the American Pharmaceutical Association, the United Commercial Travelers of America, the National Council of Mothers and Parent-Teachers Association, and the Foreign Trade Club of San Francisco, which for several years participated in the world standardization movement under the broader title of World Trade Club, and many others.

So important was the question before the nation that the Chamber of Commerce of the United States, with 1,400 of its member organizations, appointed a special committee on the metric system. This committee studied and reported upon the proposed transition to the world standard weights and measures. On the basis of this committee's report a nationwide discussion and referendum was recommended to crystallize the opinion of American business upon this important type of progress. Meanwhile other organizations and various means of communication were active. Congress received from organizations, associations, and individuals over 105,000 petitions urging enactment of the metric standardization bill. These were placed on file with the Department of Commerce in Washington, D. C. Many of the petitions were from organizations having hundreds or thousands of members, so that all together several million individuals were represented.

In 1921, the states of California, Illinois, North Dakota, Tennessee, and Utah, with combined population of 20,000,000, through their state legislatures memorialized Congress to adopt the metric system. Other states which had previously made their wishes known were Connecticut, Maine, and New Hampshire. Since the metric system has been adopted in the sciences (whether we have war or peace)—in medicine, pharmacy, optometry, photography, physics, chemistry, seismology, astronomy, electricity, microscopy, aviation, and similar areas—it seems natural that we go a step further and include these units for *business, education,* and *life.*

Seven Congressional committees on coinage, weights, and measures in the past have reported in favor of the adoption of metric standards by the United States. None of the committees has ever reported adversely. The Stone Metric Standards Bill successfully passed two readings in the House of Representatives in the Fifty-fourth Congress. The bill was recommitted to the committee after these readings, however, and for this reason failed of passage.

American manufacturers are among those interested in metric units. The National Association of Manufacturers, with the force of its membership of more than seven thousand leading concerns in America, strongly supported metric standardization. Through its committee, popularly known as the Carnegie Metric Committee because of the prominence of one of its members, it distributed much information and wielded much influence throughout the world as well as in America. With cumulative force the metric movement grew, and organization after organization entered into the activity to secure for the United States of America the advantages of the logical decimal units and world uniformity of measures.

Prominent among the organizations which have worked consistently for the same cause is the National Wholesale Grocers Association. On October 27, 1921, a representative of the association appeared before the United States Senate committee holding hearings on the metric system. He informed the committee that his organization of 870 of the largest firms and corporations in the grocery business in the United States employed 275,000 people, did business in excess of $3,000,000,000 annually, and for ten consecutive years had passed resolutions unanimously in favor of the immediate adoption of the metric system.

It should prove interesting to the reader to see a short list of the organizations that have given support in one form or another to the movement for metric standardization in the United States. Unfortunately, of the hundreds that might be listed, only a few can be cited. These are taken from the book *World Metric Standardization,*[1] in which is compiled a large amount of valuable information on the metric movement.

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[1] See the Bibliography at the end of this article.

Some of the National Organizations in the United States Urging Gradual Metric Standardization of Weights and Measures

National Research Council
Associated General Contractors of America
United States Sugar Manufacturers Association
National Salt Producers Association
National Association of Loose Leaf Manufacturers
National Paper Box Manufacturers Association
National Ornamental Glass Manufacturers Association
National Manufacturers of Soda Water Flavors
National Refrigerator Manufacturers Association
National Tent and Awning Manufacturers Association
National Sewing Machine Manufacturers Association
National Mirror Manufacturers Association
Association of Flower and Feather Manufacturers of America
American Walnut Manufacturers Association
American Specialty Manufacturers Association
National Manufacturing Perfumers Association
National Box Board Manufacturers Association
National Association of Printing Ink Makers
The 4-One Box Makers Association (National)
National Wholesale Grocers Association
Retail Grocers Association of the United States
National Canners Association
National Preservers and Fruit Products Association
American Institute of Architects
National Institute of Inventors
Periodical Publishers Association of America
American Association of Foreign Language Newspapers
National Association of the Motion Picture Industry
Associated Motion Picture Advertisers
National Association of Music Merchants
Music Industries Chamber of Commerce of the United States of America
National Scale Men's Association
National Consumers League
National Consumers Co-operative Association
National Federation of Federal Employees
Commercial Union of America
National Association of Clothiers
American Wholesale Garment Association
National Shoe Wholesalers Association of the United States
Millinery Chamber of Commerce of the United States
Millinery Jobbers Association

National Jewelers' Board of Trade
American Woods Export Association
American Wood Preservers Association
National Association of American Wood Pulp Importers
American Metric Association[2]
American National Conference on Weights and Measures
Common Commercial Language Committee
United States Section, International High Commission
Franco-American Board of Commerce and Industry
Alliance Française
National Federation of French Alliances
Norwegian American Chamber of Commerce
Swedish Chamber of Commerce of U.S. America
Holland American Chamber of Commerce
American Society of Equity (Agricultural)
National Efficiency Society
American Society for Testing Materials
Railroad Yardmasters of America
American Warehousemen's Association
Agassiz Association (National scientific organization)
Association of Amateur Scientists
American Association of Anatomists
American Entomological Association
Mathematical Association of America
American Numismatic Society
American Genetic Association
American Physical Society
American Federation of Human Rights
American National Food and Dairy Association
National Conference of Food, Dairy and Drug Officials
National Wholesale Druggists Association
National Association of Retail Druggists
American Pharmaceutical Association
National Pharmaceutical Service Association
National Drug Trade Conference
American Drug Manufacturers Association
National Association of Drug Clerks
American Nurses Association
American Medical Trade Association
American Surgical Trade Association
American Academy of Medicine
American Medical Association
American Association of Pathologists and Bacteriologists
American Optometric Association

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[2] Now named the Metric Association.

Independent Order of Foresters
Knights of the Golden Eagle
Modern Brotherhood of America
United Commercial Travelers of America
Travelers' Protective Association of America
National Congress of Mothers and Parent-Teachers Association
National Child Welfare Association
National Kindergarten Association
National Women Lawyers Association
War Mothers of America
National Council of Catholic Women
National Catholic Welfare Council
Rainbow Division Veterans
National Association of Naval Veterans
Electrical Manufacturers Export Association
American Institute of Electrical Engineers
National Association of Electrical Contractors and Dealers
Institute of Radio Engineers
American Institute of Chemical Engineers
Institute of Makers of Explosives
American Association of Pharmaceutical Chemists
American Electrochemical Society
Society of Chemical Industry
American Chemical Society
Association of Official Agricultural Chemists
Association of American Agricultural Colleges and Experiment Stations
National Academy of Sciences
American Association for the Advancement of Science

The foregoing national organizations are themselves composed of many local and state organizations; hence the combined weight of their influence represents many millions of members. Following are some international organizations that have also officially expressed a desire for metric standardization.

World Organizations Among Those Urging Gradual Metric Standardization of Weights and Measures[3]

League of Nations
International Red Cross
Pan-American Financial Conference
Pan-American Federation of Labor

[3] *World Metric Standardization.* See the Bibliography at the end of this article.

Pan-American Commercial Conference
Pan-American Scientific Congress
Inter-American High Commission
Customs Congress of the American Republics
International Postal Congress
International Electrical Congress
International Institute of Agriculture
International Brotherhood of Electrical Workers
International Metallurgical and Chemical Society
International Geneva Society of Hotel and Restaurant Employees
Inter-Allied Scientific Food Commission
Inter-Racial Council
International Correspondence Schools
International Map Committee
Babson's World Statistical Organization
World Bureau of Weights and Measures
World Metric Standardization Council
World's Sunday School Association
International Esperanto Association
International 100% Club (United States of America and Canada)
Northern White Cedar Association (United States of America and Canada)
International Association for Exports

The American Metric Association was organized December 27, 1916, at Columbia University. The first organizations to become members, offer financial aid, and otherwise lend their support were the National Wholesale Grocers, National Canners, American Chemical Society, National Wholesale Druggists and National Retail Druggists, American Pharmaceutical Association, American Drug Manufacturers, and the American Association for the Advancement of Science. As the movement grew, individuals from practically every profession and corporation joined in increasing numbers. Through annual conventions and publications in the 1920's education and influence were on a high plane. Metric leaflets, charts, rulers, crossword puzzles, and so on, were distributed at meetings and conventions and mailed to inquirers. Over 30,000 copies of the booklet *Metric Weights and Measures* were sold by 1925, and a fourth edition was issued, revised and enlarged. Exhibits were promoted at scientific and professional conventions. Lectures were given to all kinds of groups. More than fifty writers of arithmetic textbooks were asked to cooperate by supplying metric materials in the books they wrote. Prizes for debates on the subject of metric measures were offered to more than six hundred colleges. The Metric Association also had technical staffs to aid manufacturers who wished to make the change to metric units.

It would appear that nothing stood in the way of placing the United States on a metric standards basis, but history has shown otherwise. The opponents of the metric system were relatively few—only about 1 per cent in the case of the petitions, numbering more than 100,000, received by Congress in this connection. The chief deterrent in the United States during the 1920's appears to have been a lack of appreciation and understanding of the true merits of the metric system. Prejudice, indifference, and adverse lobbying doubtless had much to do with our failure to secure the needed legislation during this period. The 1929 crash and prolonged depression, followed by preparation for war and participation in World War II, later forced attention in other directions.

Nevertheless, education in the metric system of weights and measures has continued through the years, and increased interest on the part of various individuals, groups, and organizations has become apparent. In 1932 the Amateur Athletic Union of the United States adopted the metric system. This action was taken largely as a result of the Olympic Games, which were held in Los Angeles in that year and which are always conducted in metric terms, and through the work of A. C. Gilbert of New Haven, Connecticut, a member of the Olympic committee. All outdoor national track championships are now conducted in metric distances. In 1944 the Council on Pharmacy and Chemistry of the American Medical Association decided to adopt the metric system exclusively in its publications. The United States Pharmacopoeia will be rewritten in metric terms. In a recent survey of four prescription pharmacists in Chicago, one reported that 25 per cent of the prescriptions were written in the metric system, a second reported 40 per cent, a third 70 per cent, and a fourth 75 per cent. A number of physicians used both the metric and apothecaries' units in prescriptions. The *American Druggist* has said,[4]

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[4] Reprinted from the March, 1944, issue of *American Druggist* by special permission of the publishers.

"The end of confusion is near because the recent action of the AMA opens the way for universal adoption of this system." Let us hope that the Congress of the United States and the President will soon enact into law a metric standardization bill.

It is interesting to note the connection between wars and the metric system. War hastens trends and precipitates change. First, the French Revolution brought about the advent of the metric system in 1799. After the Prussian War in Europe in 1871, Germany, Austria, Hungary, and their dependent colonies adopted the metric system, almost doubling the population using metric measurements. In 1866, after the Civil War in this country, the system was made legal by act of Congress. In 1920-1921 after World War I the metric system was adopted for official use by Russia, China, Turkey, and Japan—thus the population which was on a metric basis was more than doubled. It is to be hoped that the experiences of World War II will bring about further advances in the metric standardization of measures.

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2. The System at Work

EVALUATIONS AND ENDORSEMENTS
OF THE METRIC SYSTEM BY USERS IN
WIDELY VARIED FIELDS OF ACTIVITY

Education

Shall We Educate Our Children for Efficiency?

JOY ELMER MORGAN

CHILDREN cannot be taught to be efficient by using clumsy tools and processes in the schools. When the schools take two hours to present what should be taught in one, the loss is greater than the mere time involved, for the chances are that the child will go on through life taking two hours for what could be better done in one. He will be satisfied to be a second-rater when the power is his to be a first-rater. Arithmetic is one of the foundation stones of the common school curriculum. The power to measure easily and accurately and to make calculations about the materials he uses is important to the success of any individual. Without that power to measure and compare values he is a slave to what others tell him—the victim of an incomplete education.

Just now a mastery of measurement is especially important because human relations have been greatly extended and accurate measurements are used at many points where guesses were satisfactory in a simpler period of life. There is no sadder spectacle in America than the effort to teach more than 20,000,000 school children to understand and use units of measurement which adults do not and cannot remember. It is one of the first laws of the psychology of learning that facts are best remembered in association. Our muddle of English units totally ignores this law. The metric units, on the other hand, are built upon natural associations. The child is simply taught the meter and its subdivisions. He is taught that a cubic measure one-tenth of a meter each way is the world quart and that this world quart filled with water weighs 1 kilogram. With these easily remembered relationships and a few prefixes and suffixes he can solve any problem in length, volume, or weight accurately and quickly.

Some people have derived a wrong impression of the metric system from the practice in certain older school arithmetics of teaching each metric unit with an equivalent in English units. This keeps the child's mind on words and not on the actual task of measuring things. Give him a metric ruler, a world quart measure, and a set of scales marked with metric units and set him to work on concrete objects and any child will learn to use the metric system in an hour, as hundreds of thousands of students are doing in high school and college every year when they take up the study of the sciences where the metric system is the recognized standard.

There is another important pedagogical problem in measurement. Arithmetics used to abound in what were called compound denominate numbers. Children added, multiplied, divided, and subtracted quantities expressed in such series of units as barrels, gallons, quarts, pints, and gills. For each set of measures the child had to learn how to carry over totals to the next higher units. The task became so deadly as a school problem that calculations of this kind, which are really valuable in life, are being banished from school textbooks. Our top-heavy measuring tables have already broken down in the schools. On the other hand, the metric system recognizes that the mathematical calculations of the civilized world are based on a system of tens, each of which is given a place value when it is written. Take, for example, the figure 1,926. The first place at the right is given to units, and each place to the left multiplies the value by 10 up through tens, hundreds, thousands, and so on. Every child in every country learns these relationships and uses them easily.

Few people seem to appreciate or realize what a tremendous amount of simplification would be effected (both for ourselves and our children) if operations in common fractions and denominate numbers could be carried out under the same rules as those governing whole numbers. If the child works out the following problem in addition, he adds the four 6's, gets 24 as the sum, and carries the 2 over to the tens place.

1926
1926
1926
1926

In metric measurements these relationships remain the same, a fact which means that if a child is adding or subtracting these decimal units he carries over just as he would in ordinary numbers. If, on the other hand, this sum of 24 represents inches, the child must divide by 12 before carrying over. If it represents ounces, he must divide by 16. If it represents quarts, he must divide by 4 to reduce to gallons, and so on through a whole series of unrelated units. No wonder that the lack of sense in the arrangement often so discourages the child with his arithmetic that his entire schooling is made a bugbear and he enters adult life with a sense of depression and inferiority!

To get a simple basis of comparison, take a problem from a French textbook showing what the French child learns and compare it with what an American child learns.

We ask an American school child to calculate the volume of a cubical tank 6 feet 9 1/2 inches each way, filled with water. We ask the French school child to calculate the volume in meters and the weight in kilograms of a cubical tank 2.07 meters each way, filled with water. The French child puts that down as a purely decimal proposition. He works it out by using forty-four characters and manipulating those decimals. The English or American child, in order to get the answer, has to write down and add up and divide and work out 243 characters, multiplying by that plan the possibility of error in writing the wrong characters and adding that much to his labor. The first child calculates the volume in cubic meters and then knows that a cubic meter contains 1,000 liters. He simply moves his decimal point over three places, which he has already learned to do in the decimal system.

Exhibit A. What the French Child Learns. Given a cubical tank 2.07 meters each way, filled with water. To find: 1. Volume in cubic meters. 2. Volume in liters. 3. Weight of water in kilograms.

1. Multiplying width by length by height, the child gets:

$$\begin{array}{r}
2.07\\
2.07\\
\hline
1449\\
414\\
\hline
4.2849\\
2.07\\
\hline
299943\\
85698\\
\hline
8.869743
\end{array}\ \text{cubic meters}$$

2. Since there are 1,000 liters in 1 cubic meter, the child multiplies by 1,000, by merely moving the decimal point three places, getting the second result 8.869.743 liters (world quarts).

3. Since a liter of water by definition weighs 1 kilogram, the child merely changes the name, writing 8,869.743 kilograms.

It should be noted that the child can reduce any of these results to larger or smaller units merely by moving the decimal point to the left or right respectively. The child thus understands easily not only the units of each table, but relationships between the units in the different tables.

Exhibit B. What the American Child Learns. Given a cubical tank 6 feet 9 1/2 inches each way, filled with water. To find: 1. Volume in cubic feet. 2. Volume in gallons. 3. Weight of water in pounds.

The child first reduces 6 feet 9 1/2 inches to 81.5 inches, then multiplies width by length by height:

$$\begin{array}{r}
81.5\\
81.5\\
\hline
4075\\
815\\
6520\\
\hline
6642.25\\
81.5\\
\hline
3321125\\
664225\\
5313800\\
\hline
541343.375
\end{array}\ \text{cubic inches}$$

1. The child then divides by the number of cubic inches in

1 cubic foot (1,728, a figure which is not easy to remember) to get the first result—the volume in cubic feet:

```
          313.277  (plus)  cubic feet
1728 ) 541343.375
       5184
        2294
        1728
         5663
         5184
          4793
          3456
          13377
          12096
           12815
           12096
             719
```

2. To get the volume in gallons, the child divides the total number of cubic inches in the tank (541,343.375) by the number of cubic inches in 1 gallon (231, another figure not easy to remember).

```
          2343.477  (plus)  gallons
231 ) 541343.375
      462
       793
       693
       1004
        924
         803
         693
         1103
          924
          1797
          1617
           1805
           1617
            188
```

3. To get the weight in pounds, the child multiplies the num-

ber of cubic feet by 62 1/2, the pounds in 1 cubic foot of water.

313.277 (plus) cubic feet
62.5
1566385
626554
1879662
19579.8125 pounds

Note that if the child wishes to reduce any of these results to larger or smaller units, he must multiply or divide by such clumsy equivalents as 27, 1, 728, 4, 8, and 16. There is also an inaccuracy of about 11 pounds, owing to the dropping of clumsy fractions.

This is but one type of problem. There are many others which must be taught if the child is to be able to calculate in various kinds of measures. These other types involve addition, subtraction, multiplication, division, and reduction to larger and smaller units in each of the different and unrelated tables of measure: length, area, and volume, capacity, weight, liquid, and dry.

The result is that the American child learns less and takes longer to do it than his French or German cousin. Because of poor tools he is not able to develop the skill in handling measures that is enjoyed by children in countries using the metric system. Comparatively few grown men and women in America can give easily the various tables of measures used in our daily life.

These are not theories. They are plain facts that anyone can understand. I have learned both systems. I have taught both systems. When I began studying science in high school, we learned all about the metric system in forty minutes and used it thereafter in our calculations. Teachers who know these things should make their influence felt. Every adult owes a debt to the children: to make their path easier by applying what his experience has taught him. Many of the patriots of one hundred and fifty years ago who worked to give this country political freedom advocated the use of the metric system. As they strove for political freedom, let every teacher, every parent, and every statesman work to free the American school child from antiquated weights and measures that now hold more than 20,000,000 eager learners in a form of intellectual slavery.

Comments and Resolutions on the Metric System

JOURNAL OF THE NATIONAL EDUCATION ASSOCIATION

I AM thoroly in favor of the widest possible use of the metric system in education, industry, and everyday life. It is scientific, logical, and easy to use and furnishes a necessary base for international cooperation in science and industry. The use of the metric system thruout our life based on a thoro teaching of the system in our schools would be a great advantage. It would simplify the work of education. Children are confused and delayed in their learning by the miscellaneous and clumsy tables that have grown up in our English and American usage. If we will substitute the metric system children must be brought to understand not only the system itself which is relatively simple, but also the difficulties of making the change from present measures over to the metric scheme, and the great advantage of making that change.

Joy Elmer Morgan
Editor

June 13, 1946

U. S. COMMISSIONER OF EDUCATION

THE universal adoption of the metric system of weights and measures would pose no great difficulties for the schools. Indeed, if the schools were to teach only the relatively simple metric system, the task of teachers and of students would be immeasurably lightened.*

J. W. Studebaker

THE NATIONAL SCIENCE TEACHERS ASSOCIATION

AT PITTSBURGH on July 4, 1944, the National Science Teachers Association made the following resolution its first piece of business.

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* Reprinted from *This Week* Magazine, April 16, 1944. Copyright, 1944, by the United Newspapers Magazine Corporation. By permission of *This Week* Magazine and of J. W. Studebaker.

Metric resolution, adopted by the Association unanimously:

WHEREAS, the present practice in the United States involves the use of many and various methods of measurements which in total are a conglomeration which is cumbersome to learn and unwieldy to use, and

WHEREAS, the metric system furnishes the most simple, self-related and convenient units which may be handled in decimals —just as is our monetary system—and

WHEREAS, practically every country in the world, except the United States and Great Britain, has long since converted to the metric system both internally and internationally, and

WHEREAS, in the United States many industries (e.g., electrical, American Medical Association, United States Army—about 90%) have already adopted the metric system, and

WHEREAS, the majority of men in service and many of those in industry are already familiar with the metric system, and

WHEREAS, at the time of retooling after the war it will be much less expensive for industry which is not already using the metric system to make such conversion, and

WHEREAS, in international relationships, especially trade, it will be of obvious value to use the same system used by other nations (except Great Britain) for periods ranging from over twenty years to over a century;

Therefore be it resolved, By the National Science Teachers Association, central organization of groups of people interested in science and in education in these United States, that this organization hereby urges Congressional action for post-war national adoption of the metric system of measurements.

Furthermore, the Association is hereby empowered to take any necessary action to promote the purpose of this resolution.

Drawn up and presented by
Harold W. Baker

Representatives of the Westinghouse organization, present at this action, were quick to express hearty approval. Also, the Board of Directors of the National Education Association, when informed of this action of the National Science Teachers Association, gave their support.

THE CENTRAL ASSOCIATION OF SCIENCE AND MATHEMATICS TEACHERS

At a general session of the meeting of the Central Association of Science and Mathematics Teachers held at Chicago on November 25, 1944, the following resolution was presented and unanimously adopted by the members present.

This Association, now nearly a half century old, comprises upward of 1,000 active members. Through its official journal, *School Science and Mathematics*, it has contacts with many times that number in all parts of the United States and in several foreign countries. This journal has in the past published many articles favoring a more universal use of decimals and the metric system.

Whereas, the advantages of the metric system, well known to scientists and mathematicians, would be in harmony with the simplification procedures which will be a part of the post-war reconstruction program, and

Whereas, the metric system reduces all necessary computation in measurement to the operations of whole numbers, thereby greatly simplifying the learning of arithmetic by children, and

Whereas, there has been a long steady trend in metric adoption by 55 of the 57 countries of the world, and

Whereas, there is no probability among the nations now on a metric basis of going back to the English system, thus necessitating the use of two systems with the accompanying inconvenient and time-consuming inter-conversions instead of one simple system, and

Whereas, the close of this war will furnish an opportunity never before presented, when customs and habits have been torn loose from their ruts;

Therefore be it resolved, That the Central Association of Science and Mathematics Teachers go on record as favoring some form of legislation for immediate metric usage in those lines most feasible for metric adoption.

Drawn up and presented by
J. T. Johnson
Member, Board of Directors
Central Association of Science
and Mathematics Teachers

The resolutions by teachers' associations given here are representative of the general interest among such bodies in the promotion of a wider use of the metric system in the United States. This supports the idea held by many that the movement for metric reform should start in our schools.

CONNECTICUT VALLEY SECTION, ASSOCIATION OF TEACHERS OF MATHEMATICS IN NEW ENGLAND

C. H. Sedgewick, *President*
Helen Wright, *Vice-President*
Elizabeth Speirs, *Treasurer*
George E. Frost, *Secretary*

THE following resolutions were unanimously passed at the Spring Meeting of the Connecticut Valley Section of the Association of Teachers of Mathematics in New England, April 13, 1946, held at Northampton High School, Northampton, Massachusetts.

WHEREAS, The present systems of measurement in the United States are cumbersome to learn and unwieldy to use, and

WHEREAS, The metric system reduces all necessary computations in measurement to the operations of whole numbers, thereby simplifying the learning of arithmetic and the use of arithmetic in computation, and

WHEREAS, The electrical, radio, jewelry and optical industries, the American Medical Association, the national and international sports organizations, and the United States Army are now using the metric system in whole or in part, and

WHEREAS, The metric system has been adopted by 55 of the 57 countries in the world:

Be it resolved, That this association go on record as favoring legislation by both the federal government and the various states for immediate adoption of the metric system throughout the United States, and

Be it further resolved, That this association is hereby empowered to take necessary action to promote the purpose of this resolution.

Eliot P. Dodge, *Chairman*
Wallace R. Bartlett
Alfred K. Mitchell

Science

Let's Be Scrupulous About Our "Scruples"

R. W. MATTOON

In 1821 John Quincy Adams prophesied that "the meter will surround the globe in use as well as in multiplied extension; and one language of weights and measures will be spoken from the equator to the poles." Now, over one hundred years later, the metric system is used in common practice by all major countries of the world except the English-speaking ones.

All physical measurements can be expressed with appropriate combinations of the fundamental concepts: mass (m), length (l), time (t), and temperature. For example, acceleration has the dimensions l/t^2; force is ml/t^2; and electric current (in the electrostatic system) is $m^{1/2}\,l^{3/2}/t^2$. The quantitative specification of a measurement is expressed as the product of a number and the units of measurement. Thus 5 centimeters per second is the same speed as 3 meters per minute.

Because nature seems to behave consistently everywhere, the science of physics is universal. With the acceptance and use of the single metric system of units, the language of physics has been made international. One of the very few exceptions is the following: in dealing with ruled diffraction gratings, English-speaking physicists usually refer to the number of lines per inch, instead of per centimeter, because their gratings probably were made with an integral number of lines per inch. But in practice the number of lines per centimeter is demanded. Spectroscopic wave lengths are never expressed as fractions of an inch.

The metric units are arbitrary but standard. Larger or smaller secondary units vary as powers of 10. The prefix *milli-* stands for 0.001, *centi-* for 0.01, and *kilo-* for 1,000. The *kilogram* is defined as the mass of a certain piece of platinum-iridium. The *meter* is defined as the distance between two lines on a certain bar of platinum-iridium at the temperature of melting ice. The *second* is defined as 1/86,400 of the mean solar day.

In the English-speaking countries, there are many special units of measurement, and their terminology is confusing. As an example, druggists have their own units of mass, one of which, still used occasionally, is the "scruple." The following table, in which are listed the equivalents of some other English units of mass, shows a hodgepodge of ratios.

0.05 apothecaries' scruple = 1 grain
0.15432356 apothecaries' scruple = 1 carat
1.2 apothecaries' scruples = 1 troy pennyweight
1.367187 apothecaries' scruples = 1 avoirdupois (common) dram (mass)
3. apothecaries' scruples = 1 apothecaries' dram (mass)
21.875 apothecaries' scruples = 1 avoirdupois (common) ounce (mass)
24. apothecaries' scruples = 1 apothecaries' (or troy) ounce (mass)
288. apothecaries' scruples = 1 apothecaries' (or troy) pound
350. apothecaries' scruples = 1 avoirdupois (common) pound

This table becomes very much simpler if one converts to grams by using

1 apothecaries' scruple = 1.2959784 grams
or 1 avoirdupois (common) pound = 453.5924 grams

and then merely uses the metric units:

1,000 milligrams = 1 gram
1,000 grams = 1 kilogram

The apothecaries, and in fact the members of the entire medical profession, are now rapidly converting to metric units.

In regard to lengths, the inch is equal to 2.54 centimeters for all practical purposes. In the metric system:

10 millimeters = 1 centimeter
100 centimeters = 1 meter
1,000 meters = 1 kilometer

When dealing with volumes in the English system, one must remember that 1.200942 United States gallons = 1 British imperial gallon. The relations between gallons, quarts, pints, gills, and fluid ounces are confusing. Then too, there are fluid *ounces* for volume, avoirdupois *ounces* for mass, and troy *ounces* for mass, all in common practice. It is much easier to remember only that

1,000 cubic centimeters (or milliliters) = 1 liter

Fortunately, the whole world accepts the *second* as the unit of time. However, the international custom of naming the hours up to 24 instead of denoting A.M. and P.M. would be a "timesaver." Also, endless confusion would be minimized by the adoption in 1950 of the world calendar proposed by Elisabeth Achelis of The World Calendar Association, Inc.[1]

The centigrade temperature scale, suggested by Celsius in 1742, is rational. The temperature at which water freezes means much in our living, for below that point inland shipping ceases, drinking water freezes, precipitation changes to snow, and walks and streets become slippery. It is most appropriate to call this temperature zero; then a negative temperature denotes freezing, whereas a positive one does not. Likewise, the temperature at which water boils is important, and it is convenient to denote this temperature as 100. Fahrenheit in 1714 chose zero as the lowest temperature obtainable with a salt-ice mixture (but it wasn't quite), and 96 as the normal human temperature (we'd all be sick!). There's nothing unique about 32° or 212° Fahrenheit, so let's use 0° for the temperature at which water freezes and 100° for the temperature at which water boils.

The United States and Canada have a decimal monetary system. The calorie is replacing the British thermal unit. Labels on canned goods and boxes are being marked also in grams and liters. The world is steadily growing smaller. Let's go metric, step by step, and be scrupulous about our "scruples."

The Metric System in Chemistry

HAROLD W. BAKER

To ANYONE working in the field of chemistry, a change to exclusive use of the metric system would be a very simple matter—and more than welcome. Elimination of non-metric units would facilitate practically every application of measurements in relation to chemistry.

The size or type of unit of measurement is a matter of indifference to the producer of raw materials. The railroads or other common carriers either are using metric measurements or could make the conversion with a minimum of difficulty.

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[1] International Building, 630 Fifth Avenue, New York 20, N. Y.

Chemical manufacturers are already using metric measurements to a large degree. All their foreign trade except that with British countries requires metric units, and now that the medical profession demands standardization on a metric basis, there is little field left for use of other measurements for chemicals. All of the metric units are convenient in size, and conversion scales or factors are a simple solution for making the change to complete use of the metric system. Specific gravity is itself a metric unit; the old use of density is rapidly fading from the picture.

Any slight amount of equipment which the manufacturers would have to replace or recalibrate would be fairly well worn out within the suggested ten-year conversion period. In many cases there would be no greater need than a replacement scale of metric units.

Merchandising of chemicals to the average purchaser would actually be facilitated by the use of metric units, because of the simplicity of the decimal multiples. In school laboratories it would be extremely desirable to eliminate the confusion caused by other than metric units. The writer cannot recall a single instance in over thirty years of chemical work wherein any other units would be as convenient as those of the metric system.

In calculations dealing with gas volumes, the metric system is standard. In computation of percentages for any purpose, the decimal system saves work and possible confusion. Volumetric and gravimetric measurements are all metric.

We could dispense entirely with the Fahrenheit temperature scale. If necessary, a conversion table or equivalent scale could be used until all vestiges of Fahrenheit use have disappeared. In this field, as in all others, standardization upon metric units would mean simpler and more exact calibration of instruments; such instruments could thus save time and give more trustworthy results. Then, too, there would be no problem of conversion of units as in an unwieldy, unscientific English system.

Mentioned elsewhere is the definite double saving of time and effort that would result if the metric system were the only one taught in our schools. Fractions would become—as they are in chemical problems—merely indicative of divisions or proportions.

It is interesting to note that electricity, radio, and medicine use metric measurements exclusively. If the various industries which have already converted to the metric system have found it a financial saving within a short time, certainly other industries would similarly profit by the change. The U. S. Coast and Geodetic Survey used metric measurements for its recent job covering the country. We even have to pay our taxes on the decimal system!

Only the British Empire and the United States have been backward in this matter. Are we going to be blind enough and stubborn enough to forfeit our share of world trade to the countries which are smart enough—yes, almost every other country in the world—to see the advantages inherent in metric measurement? Science *leads* the way.

The Metric System in Meteorology

CHARLES F. BROOKS

ALTHOUGH meteorologists in their everyday work for the public must talk in terms of inches and feet and miles when referring to rainfall, snowfall, or wind velocity, in their scientific work they can employ the metric units, which in many respects are more convenient. In the measurement of precipitation the standard in use in most countries is the millimeter. It is possible to measure light rainfalls down to 0.1 millimeter, but climatic tables are normally published in whole millimeters, which is certainly close enough for practical use, in view of the uncertainties of measurement. Whole millimeters require less space for printing, and since they have no decimal point to get misplaced, there is less chance for error.

Measurement of snowfall in centimeters, and, in the case of light falls, in millimeters, is, for the same reasons, more satisfactory than in inches. Owing to the greater uncertainties of snowfall than of rainfall measurements and to the fact that the water equivalent of snow is approximately one-tenth its depth, snowfall data are normally published only in whole centimeters.

In wind measurement it is anomalous to employ miles per hour except in connection with flying or knots except in connection with navigation or naval aviation. Only then does the mileage of the wind have significance. Much more to the point is the designation of speed in terms of meters per second. Here, too, the metric unit is more reasonable than the non-metric miles per hour. One meter per second is roughly equivalent to 2 1/4 miles per hour or 2 knots. An accuracy of measurement to 1 meter per second is about as good as anemometers can be expected to give.

In aerological work the metric units of height, namely, meters and kilometers, are much more convenient than feet and miles. In fact, we have the somewhat inconsistent fashion of talking about aerological heights in kilometers and horizontal distances in miles. A balloon is weighed and its free lift determined in grams. Its diameter is measured in meters. A balloon containing 1 cubic meter of hydrogen can lift approximately 1 kilogram. This fact is very convenient in making calculations. The balloon when released ascends at so many meters per minute.

In theoretical meteorology there is a relationship between temperature and change in height of a mass of air, which in metric units is the very convenient value of 1° centigrade per 100 meters. This is the rate at which air is cooled by the work it does in expanding as it rises—the rate observed normally below cumulus clouds on a sunny day. It is called the *dry adiabatic lapse rate.*

In the measurement of atmospheric pressure, millibars, which are pressure units, have replaced inches or even millimeters, which are linear units, in the weather services of the world. Before this change, pressure was measured as temperature would have been had we used a ruler to measure the length of the mercury column on a thermometer in inches or millimeters instead of reading degrees direct. The millibar is a dynamic unit and is defined as a pressure of 1 kilodyne on 1 square centimeter. The bar, or 1 megadyne pressure on 1 square centimeter, is the megadyne atmosphere of meteorologists. It is a little less than the standard atmosphere, which is 1,013.3 millibars; but, since it represents the average pressure at only 106 meters above sea level, the megadyne base is the standard in pressure computations by meteorologists. Unfortunately meteorologists, when they applied the term *bar* to 1 megadyne per square centimeter, did not realize that only a few years earlier physicists and chemists had used this term for a unit of pressure a million times smaller, only 1 dyne per square centimeter. The late Alexander McAdie fought unavailingly for decades to get meteorologists to abandon their new bar in favor of the old and to use the kilobar, rather than the millibar, for the convenient unit of pressure for tables and weather maps.

By use of millibars instead of inches meteorologists carry refinement in barometer reading to the nearest tenth of a millibar, instead of to the meaninglessly refined thousandth of an inch (one-third as great) or hundredth of a millimeter (one-eighth as great). Publication is facilitated by omitting the hundreds, for the pressure at sea level rarely goes below 950 or above 1,050 millibars.

I have not mentioned thermometer scales, since they are not strictly in the metric system, but here I should like to describe the Kelvin-kilograd scale devised by the late Alexander McAdie. This scale calls for 1,000° between absolute zero and the melting point of pure ice. The units of this scale are conveniently small. They are about half the Fahrenheit degree and therefore about the right size for meteorological purposes. There is no need for temperatures in tenths of kilograds except in psychrometric work. And, as on all absolute scales, there are no negative temperatures. In ordinary meteorological work Fahrenheit is preferable to centigrade, but the kilograd is still better. For human purposes, however, the Fahrenheit scale, with its range from zero to 100, from the "extremely cold" to the "extremely hot," is almost perfect, even though in the strict physical or thermodynamic sense these numbers are without significance.

Radiation is measured by meteorologists in terms of gram calories per square centimeter per minute; or, rather, the measurement is made in terms of the deflection of a galvanometer in microamperes or millivolts and then converted to calories. When it comes to applying solar radiation values to the needs of architects in planning house heating in different climates, the values must be converted to British thermal units per square foot, thus giving unnecessarily large numbers to deal with. For instantaneous values, the intensities are stated in calories and hundredths; but for daily values, they are stated in whole calories.

These are a few of the uses to which metric units are put in meteorology and in which they are definitely superior to the English units now in popular use from the standpoints both of convenience in use and of economy in publication.

Resolution in Favor of the Metric System

AMERICAN ASSOCIATION FOR
THE ADVANCEMENT OF SCIENCE

Whereas, The metric system of weights and measures has not yet been brought into general use in the United States, and

Whereas, The American Association for the Advancement of Science has already adopted and published resolutions favoring the adoption of the metric system of weights and measures in the United States; therefore, be it

Resolved, That the American Association for the Advancement of Science reaffirms its belief in the desirability of the adoption of the metric system of weights and measures for the United States, and recommends that the units of that system be used by scientific men in all their publications, either exclusively or else with the customary non-metric units in parentheses.

Adopted by the Council

December 29, 1922

Engineering

The Metric System in Electrical Engineering

A. E. KENNELLY

There are at present four main divisions of engineering (excluding military engineering), namely, civil, electrical, mechanical, and mining engineering. Each of these subdivides into various recognized branches so that there are in all nearly forty different branches of engineering. They all rest upon the same fundamental sciences: chemistry, economics, mathematics, and physics, using these latter terms in their broad meanings.

Electrical engineering may be described as that division of engineering in which emphasis is laid upon the applications of electricity and magnetism. From this point of view, electrical engineering is merely one division of the entire field and very much younger than the other divisions.

Although electrical engineering is relatively young, it has gained great importance all over the world. It is not only assuming a prominent role in the general field of engineering, but it is also entering into the specialized work of the other divisions of the science. It has made extraordinarily rapid strides in the last forty years, both in this country and internationally.

Various reasons might be offered for the relatively rapid growth of electrical engineering science. As will be generally admitted, one reason is that the electrical units employed in electrical engineering are the same all over the world and are associated with the international metric system of weights and measures. Whereas the units employed by civil, mechanical, and mining engineering, such as the foot-pound, the gallon, the inch, or the acre, are different in the English-speaking countries from those in other countries, the electrical units have everywhere the same meanings and values. International use of standard units is of great advantage to the progress of an applied science. Ideas spread rapidly and transplant themselves readily under such conditions.

The internationally adopted electrical units are: the volt (after Volta), ohm, ampere, watt, joule, coulomb, henry, gauss, and maxwell. One of these (henry) is named after an American electrician; three (joule, watt, and maxwell), after Englishmen; two (ampere and coulomb), after Frenchmen; two (gauss and ohm), after Germans; and one (volt), after an Italian. All these units are defined as decimal derivatives of the metric system. Their standards are maintained in the various national laboratories according to international specifications by which the units may be precisely reproduced. Thus, in the United States, the standard international volt, ohm, ampere, and so on, are maintained at the National Bureau of Standards in Washington, D. C. An international ohm, as thus determined in the United States, is the same as an international ohm determined in London, Paris, or Rome to a very high degree of precision. There are certain minute discrepancies between the above-named international electrical units thus standardized and the theoretical metric values on which they are based, owing to the necessary imperfections of physical knowledge and measurement at the time (1908) when the standard specifications were adopted. Thus there is a certain minute difference between the theoretical metric ohm and the actual international ohm; but the difference between them is so small that it has not yet been agreed upon internationally. If the difference should be agreed upon, it is not likely that the international ohm would be changed. A small numerical correction would probably be applied in the special cases where the highest scientific accuracy was needed. The first standard ohm was issued in England by the British Association for the Advancement of Science about 1865. It was called the "British Association ohm." With it were associated a British Association volt and other standards. The British Association ohm was found to be too small in relation to the true theoretical ohm, by more than 1 per cent. A new standard ohm was issued internationally in 1882, called the "legal ohm," and was more closely adjusted to the theoretical value. The present international ohm was agreed upon internationally in 1893, and made a still closer adjustment to the theoretical value. It is likely to remain unchanged for some time, since the outstanding error is relatively very small.

It is not to be supposed that the use of these metric units is exclusively electrical. The joule as a unit of work or energy, and the watt as a unit of activity, rate of working, or power, are indeed electrical units; but they are also and equally mechanical or chemical units. It is both accurate and convenient to measure mechanical power either in joules or in watt-hours. Moreover, to give an idea of the present widespread use of these metric units in America, it will suffice to remember that electrical energy is sold universally in terms of the kilowatt-hour, or 1,000 watt-hours, whether the electric energy has been utilized to drive motors, heat furnaces, or operate lamps. Every month hundreds of thousands of bills for electric energy are presented and paid, all on the kilowatt-hour basis.

In the study of the principles of electrical engineering, a knowledge of the underlying metric system—the meter, liter, and gram system—is required. It is probably correct to say that all the colleges in the United States which teach chemistry, physics, or electrical engineering either call for, or instill, a knowledge of the metric system among their students.

The rapidly extending use of radio telegraphy—the so-called "wireless telegraphy"—has also greatly developed the use in this country of the international meter; because all international wave lengths are in meters, and the new broadcasting stations publish the lengths of their waves in meters in the daily papers for the benefit of amateur receiving stations. Is it any wonder, therefore, that the metric system is steadily infiltrating our daily press, our magazines, and general literature, since electrical engineering is so active an advertising agent?

While this article was being written, an interesting book came into the writer's hands which serves aptly as an illustration of the way in which the international metric system is coming into general literature. The book is called *Wind and Weather,* and was written by the meteorologist Alexander McAdie. It is a charming exposition of the ways of the winds, written for the public and not for specialists. It uses metric units without apology and without pretense. About one-third of these metric expressions are accompanied by corresponding parenthetical non-metric expressions.

At the present rate of advance, even these parenthetical nonmetric equivalents will probably become superfluous in the not far distant future. We may readily remember that the meter is roughly a yard, not so much as 10 per cent longer than a yard; so that we might describe a meter as the international yard. Similarly, a pound is roughly a half kilogram, and the half kilogram is in excess of our pound avoirdupois also by approximately 10 per cent. We might thus describe the half kilogram as the international pound. In France today the word *livre* (pound) is used to mean the half kilogram, except in historical references to the old French pound. Again, the liter is roughly equal to a United States liquid quart, and the liter exceeds our liquid quart by about 6 per cent. We might thus describe the liter as the international quart. We already have the international carat (200 milligrams) for dealing with diamonds and other precious stones. This has been adopted by the U. S. Bureau of Customs with great success. Today everyone can readily understand what is meant by an international carat; whereas a few years ago, before the metric value was adopted, there was much confusion associated with the word *carat* in international trade.

In view of the fact that electrical engineering has already introduced the units of the metric system into widespread public use, there is no question as to whether the system will be generally adopted in the United States. The only question is how soon it will become generally adopted. There are various opinions as to the answer to that question, but if we compare the general literature of the present day with that of a generation ago, we can realize how rapidly the change is coming. More than fifty countries have already made a change from their local measurement systems to the metric system, and not one has expressed a desire to go back.

The Metric System in Mechanical Engineering

LOUIS ELLIOTT

PRACTICALLY all the countries in the world except the English-speaking—which, indeed, contribute most heavily to volume of manufactures and of commerce—have legally adopted the metric system of weights and measures and use it in all sorts of transactions. As a consequence there is an undesirable discrepancy between the practice of the United States and British countries and that of the rest of the world, paralleling the differences in language and custom and, like them, contributing to general difficulty in international intercourse.

Grave difference of opinion prevails in this country between opponents and advocates of the metric system as to the advisability of adopting it in manufacturing and trade. This change might be accomplished sooner or later through education, through action by various public or private bodies, or through legislation. No thorough study has yet been made by governmental agencies or others of the advisability and cost of adopting metric measures in place of the so-called English "hodgepodge." While some of the objections to the metric system have resulted from study of the situation and represent sincere opinion, many, on the other hand, have been the result of prejudice and of shortsighted selfish interest, and have had no factual basis. There have been statements of doubtful validity to the effect, for instance, that the inch, the foot, and the pound are inherently more convenient in magnitude than the centimeter, meter, and kilogram, or that differences in convenience vary with the uses to which these units are put but are negligible, given equal familiarity with both.

It is quite natural, as a result of inertia and conservatism, that a radical change of this character in current practice should be opposed by those who are reasonably satisfied with existing weights and measures and who would incur a substantial expense by conversion for a future benefit that cannot definitely be evaluated. In most lines of work relatively few weights and measures are required, and familiarity with these and their subdivisions makes them appear simple and easy to use.

Scientists and educators in general favor the metric system. There is a considerable group of sincere metric advocates who have no dollar stake in conversion. On the other hand, many manufacturers are opposed to metric measures and state that conversion, gradual or rapid, would entail great cost and that the English system of weights and measures is better than the metric. The prevailing influence to date has naturally been that of the groups advocating the status quo, who have a substantial monetary stake in the matter. It is recognized that conservatism on the part of engineers and others in this country, attachment to the English system of measures, and long familiarity with its use—which means ability to get definite conceptions of values expressed in that system—militate against thoroughgoing adoption of the metric system in the United States.

USE OF METRIC MEASURES IN ENGINEERING PROJECTS

A number of engineering firms were asked some time ago about their practice and general opinion in regard to using metric measures in analyzing problems and preparing plans, especially for foreign clients. It was found that engineering firms frequently utilize metric weights and measures in work on foreign projects. In practically all cases, however, it appears necessary or advisable to make certain drawings to both English and metric measures or to English measures only, particularly for material or equipment manufactured in the United States. For construction plans of work to be undertaken in the foreign field—such as those showing building and equipment foundations and those covering general plant arrangements—metric measures are more freely used, with less English admixture. Indeed, some Latin American countries require the filing of plans showing project outline and important details in the legally adopted system of measures, that is, the metric. The testimony with respect to introduction of metric measures in American drafting rooms is that little or no difficulty is experienced.

Over the past thirty years the engineering firm with which the writer is connected has prepared to the metric measures designs for electric power stations aggregating 200,000 kilowatts in capacity, and to the English measures designs for stations of several million kilowatts' capacity. Property dimensions and elevations in metric designs are given in one unit only—the meter—and engineering plans of power or industrial plants or of equipment also use one unit—the millimeter. Dimensioning on any one drawing is therefore of the utmost simplicity, avoiding the usual multiple units, such as feet and inches and the awkward fractions of the latter. Compare, for instance, the design of a steam turbine drawn to English measures with one in metric units. The simplicity of the latter is evident.

It is found that engineers and draftsmen who are unfamiliar with metric units can soon learn to use them economically in design work. In work for foreign clients there is, at present, the difficulty arising from disparities between American and foreign standards. Reconciliation of such standards would be of great benefit to those engaged in engineering work for foreign countries and would improve the position of the United States in this field.

DeLaval Separator Company has been using the metric system for about thirty years for all its designs. The management of that company is convinced that the cost of conversion by an industry from the English to the metric system would be reimbursed within a few years by the resultant economies. There are wide differences in the cost and complication of converting various types of machinery. Parts of screw-cutting machines, universal millers and automatic gear-cutters, for instance, would have to be modified or replaced. Other types of machinery, such as planers, production millers, drills, and boring mills, could be used without much, if any, modification. There would be substantial extra expenditures for new scales, micrometers, and gages, and for jigs, templates, and patterns if these were converted to the metric system before they were worn out or otherwise obsolete.

American manufacturers, sales concerns, and engineers who supply equipment or service to Latin American and other metric countries would certainly find an advantage in adopting the metric system for such work, in conformity with local legalized and approved practice with respect to weights and measures. One of the advantages that German and other European competition has had during past decades in South America is that goods, engineering equipment, and structures, as well as services, have been supplied on the basis known and desired by customers. Once American firms discovered that these are profitable practices, the revised standards could be adopted without great difficulty. This is indicated by the ability of American manufacturers to produce guns and other war matériel to metric measures, as well as by peacetime utilization of metric standards by many industrial concerns in this country.

The outlook for keen competition with Europe for Latin American trade indicates that United States manufacturers, technicians, and governmental authorities should make early plans for placing this country in a favorable position to trade. Widespread use of the metric system of weights and measures would be a potent factor in this coming struggle. It would contribute to good understanding with clients and customers and would be a tangible contribution to "good-neighbor" policies.

WHAT CAN BE DONE?

What *should* be done, and what *can* be done, to reconcile the United States standards of measurement, in industry and trade, with those of the rest of the world?

The country already has a decimal series of numbers and a decimal currency. There is important utilization of metric measures in this country in laboratory and other scientific work, in pharmaceutical practice, in electrical measurements, by the U. S. Coast and Geodetic Survey in basic triangulation, by the U. S. Army in certain armament, and by important firms in manufacturing processes. Many manufacturers have designed and fabricated to metric measures, including Baldwin Locomotive, Crane, General Electric, DeLaval Separator, and makers of automotive ball bearings—especially during World War II. Some important firms, though they may not champion metric measures, are willing to go along with a movement toward gradual conversion, believing that in the end this will bring to American industry the greatest efficiency and opportunity for foreign business. Some companies have established in metric countries factories in which that system is naturally used.

One possible course for engineering, industry, and commerce in the United States is to "sit tight," effecting no wide change in the measuring system but making certain detailed changes in practice. The inch may be decimalized for machine and other work, as has been done by the Society of Automotive Engineers for airplane engine design. Catalogues may be prepared to metric measures, and metric labels and dimensions may be applied to export goods, as is now done to some degree. This course of minimum action might mean indefinitely extended use of the English system in this country, with modest compromises in foreign trade. A reported proposal that metric measures be crowded out by forcing the English system on all purchasers of equipment made in England and the United States, is most ill advised; its success would be improbable, and it would tend to separate the world into English-speaking and non-English-speaking groups.

Another course is to finance and carry on propaganda for influencing the people and Congress. This might result in radical action. However, mandatory legislation, unless supported by a majority of intelligent men in the fields affected, is seldom advisable.

A third and more rational course of action would involve a canvass, by the appropriate arm of the United States Government and by each important industrial, business, and general group in the country, to determine costs and advantages of change to metric use. A study of this kind might well develop opinion favoring conversion over a term of five, ten, or twenty years.

Minor steps could be taken promptly, such as adopting the centigrade thermometer scale in place of the Fahrenheit, using the gram in place of the ounce as the basis of United States postal rates, standardizing army and navy munitions on metric measures, printing governmental and other data in metric as well as English measures, and improving metric instruction in the schools. Metric units could be further adopted in marking equipment and materials shipped to countries utilizing that system. Later, the liter, the kilogram, and the metric ton could be introduced in domestic and foreign trade, superseding the quart and gallon, the pound, and the two English tons. Manufacturers might be left free to adopt metric measures in shop usage when and if they considered the change profitable.

WHY ACTION SHOULD BE TAKEN NOW

Through most of the industrial history of this country, technical contacts with foreign peoples have been somewhat limited and exports have not constituted a large proportion of our production. Now, however, it is hoped that there will be more nearly "one world" and that industrial contacts with all other important countries will multiply. Export trade, particularly during the next few years, should be great, and, assuming reduction in tariff, imports will be large.

The difficulties caused by differences in language and in currencies, and—particularly during World War II—by disparities in mechanical dimensioning, are well known. A fabulous value was assigned to the loss caused during the war by the confusion in screw-thread standards. Rommel's rapid advance across North Africa has been reported as resulting from inability of the Allies to restore damaged equipment by replacement parts, because of conflict in standards. These are results, in the main, of disparities between English and United States standards; how much greater loss occurs from the wider difference between English and metric measures! Practically all countries except our own and those of the British Empire have adopted metric measures. Differences between the metric and the English systems, and indeed the inconsistencies between the English and our own, constitute one of the bars to simplicity of intercourse and to easy flow of goods.

In rebuilding the world, peace and trade are necessary. The age of narrow nationalism should be over. Not all barriers can be removed, but the United States should maintain an interest in the welfare of those willing to join in creating a freer world. Aside from this broad consideration, the profit motive must raise questions as to whether or not, after general reconstruction, this country can compete effectively with nations that produce goods to the measurements and standards of the vast majority of customers in South America, Europe, and Asia.

The Metric System in Mining Engineering

STANLEY KING WALLS

ENGINEERING is defined as "the science and art of utilizing the forces and materials of nature." Mining and metallurgical engineering, in particular, is concerned with finding and extracting raw materials, using all of the forces of nature in the search for, exploitation of, and beneficiation of, mineral ores, metallic or nonmetallic, and fuels, solid or liquid.

The value of a mineral deposit is affected by location, cost of extraction, processes of concentration and refining, and transportation to its market. The possibility of competitive conditions in that market demands the maximum of efficiency in each stage of processing, and the mining engineer must satisfy first himself, and then his principal, that the revenue will be sufficient to offset all costs and yield a return over and above the cost commensurate with the risk involved.

Someone has said that "man is a measuring animal," and a mining engineer's reports—preliminary or operating—are little more than a compilation of comparative measurements.

And there, right there, is the rub. For only one of the measurements is universally understood and visualized, with no possibility of equivocation—the dollars and cents at the foot of the table. For the banker, the trustee, the speculator, or

"The widow and the orphan
Who pray for ten per cent" [1]

may be hard put to answer offhand how many square feet there are in an acre, or the weight of a gallon of water; but, one and all, they know exactly how many cents there are in a dollar and whether a return of 15 per cent, or 15 cents on the dollar, is sufficiently attractive.

A mining engineer's preliminary report might sum up somewhat as follows: "A capital investment of $56,000, plus operating expenses of $14,000 until revenue begins to come in, that is, a total outlay of $70,000, should, in my opinion, yield $21,000 per annum." Splendid—we can all understand that—why, that means 30 per cent—let's go!

But to prove that his opinion is a thoroughly reasoned one, and to avoid difficulties with the Securities Exchange Commission (should this development go ahead and pay only 25 per cent) our engineer supports this finding with fifty pages of additional measurements, and *there is no relationship between any of them!*

First of all, presumably, he has taken samples and made an assay. The report includes a sworn or notarized statement from the assayer that the samples run "4 ounces to the cubic yard." (If this is gold we are after, those ounces will, of course, be troy ounces.)

The cubic yards have to be converted into pounds for calculation of the power necessary to raise them to the surface. Underground, however, we seldom measure in yards. We use feet and inches, and every engineer uses *decimals* of a foot when he comes to calculating.

In short, all mining operations involve moving a certain *weight* and *volume* a certain *distance* horizontally and vertically. The fact that there is no relationship between volume and weight and distance only adds to the arithmetic that the engineer must do and multiplies the possibility of error.

When we consider the details, such as pumping out the water which seeps through the earth, we have to dodge back and forth from cubic feet to gallons, to pounds, to feet (of lift), to square inches (the cross section of the pipe), to cubic inches (the cross section area multiplied by the stroke of the pumps). And to put in mine timbers, we have to calculate in square inches (for strength), in feet and inches (for height and length), and in board feet to purchase them.

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[1] Rudyard Kipling, "The Broken Men," *Rudyard Kipling's Verse, Inclusive Edition, 1885-1918* (Garden City, Doubleday, Page & Company, 1926), p. 110.

A "board foot" is a compound of square feet multiplied by inches, but when we extend this compounding to enable us to calculate the bending moment in inch-pounds, foot-pounds, and foot-tons, and water storage in acre-feet, we really are, if we would stop to think a moment, making ourselves a little ridiculous. Calculating a water supply in acre-feet and the consumption of that water in gallons per capita per diem ought to bring us right up short: *Look here, are we deliberately trying to do this the hard way?*

Most of us can remember what the area of an acre is: 43,560 square feet. However, for anything over or under 1 acre, we have to sit down and multiply. To pump away an acre-foot of water, we say: 7 1/2 gallons to the cubic foot, for 43,560 cubic feet, amounts to 326,700 gallons. (Actually it is not 7 1/2 gallons to the cubic foot, but 7.4805, which makes a difference of about 1,000 gallons.) If we require the *weight* of that much water, we have first to multiply to get pounds and then to divide to get tons.

A hectare, on the contrary, measures 100 meters by 100 meters, an area of 10,000 square meters. A water source with an area of 1 hectare which was 1 meter deep would therefore contain 10,000 cubic meters; that is to say, it would hold water amounting to 10,000 tons, if we would know its weight, and 10,000,000 liters, if we are dealing with quantity.

A curious fact about this unrelated series of weights and measures which we must either memorize or refer to continually, is that actually it is illegal. The metric system, the use of which is still far from general in these United States, is the *only system ever legalized by Congress.* After the International Conference of Weights and Measures in which the United States took part in 1889, this country was presented with an exact copy of the French standard meter, and in 1893, by act of Congress, this meter was made the standard unit of length in the United States. The yard was then defined as 3,600/3,937 of that meter, but an enormous number of otherwise well-educated people continue to believe that the British yard is our standard. Actually, it was not so long ago, in 1878, that the British yard itself was definitely standardized. The yard, the gallon, the bushel, the barrel, and the various other unrelated British weights and measures which have been widely adopted in American practice have evolved from primitive times by completely unregulated processes of development.

Let us consider linear measurement alone. The Bible gives the measurements of Noah's Ark and of Solomon's Temple in cubits. The Great Pyramid of Giza was laid out in "royal Egyptian cubits." The cubit was the distance from the elbow to the tip of the middle finger. A study of Egyptian building would indicate that the royal Egyptian cubit equaled 20.7 inches. We do not know what subdivisions of the cubit were in use in Egypt. As the Egyptian civilization withered, however, and the Greek flowered, we find records that the Olympic cubit, equivalent to 18 1/4 of our present-day inches, was divided into the span, 1/2 cubit; the palm, 1/6 cubit; and the digit, 1/24 cubit, or roughly 3/4 inch.

As the Roman civilization arose, the cubit began to be known as the foot and shrank in length. It was divided into 12 "unciae," (Latin for *twelfth* or *thumbnail*), from which we get both *ounces* and *inches.*

The Romans left this "inch" in Britain as one of their standards, but it was not until 1324 that its length was defined there. In that year the inch was determined to be "the combined length of three barley corns set end to end." The yard had come into being in England about the middle of the twelfth century as an outgrowth of the archery for which the English yeomen were then famous. It was the deadly accuracy of the English archers that lost the Scots the Battle of Flodden. The Scots, it appears, instead of practicing at the "buttes" in the summer evenings, had taken up a disreputable game called "gowf." The wonder is that a race that has given the world logarithms did not establish the putter as the legal yard. No, the yard is ascribed to Henry I, and was supposedly the distance from his nose to the end of his thumb, or the length of his arrows. It was not until 1558 that Good Queen

Bess decreed that the length of a bronze rod should be the standard yard. In the sixteenth century some effort was also made to standardize the foot and relate it to other measurements. The Crown decreed that "on a certain Sunday, as they come out of church, 16 men shall stand in line with the left foot touching, one behind the other." The distance they covered, foot to foot, was to be the legal rod, and one-sixteenth of it the legal foot. Prior to that, the foot had varied (as feet will) from 9 to 19 inches.

Queen Elizabeth's prototype yard was superseded in 1824 by another, which was lost by fire after ten years. In 1878 the Weights and Measures Act defined the yard in use today in Great Britain. It was a bronze rod, which had been cast some forty years earlier, on which the standard yard was measured off between gold studs. By 1878 accuracy had progressed to the point where the temperature of the rod was specified, the temperature chosen being 62° Fahrenheit, which in those days was considered "room temperature" in Britain. The foot is standardized as 1/3 yard, and the inch as 1/12 foot.

The metric system developed in a different way. The French revolutionaries cut off their king's head and then in pursuance of their motto, "Nous avons changé tout ça (we have changed all that)," decided to be rid of every reminder of kings, not the least being a system of measurements based on some king's hands, feet, fingernails, or arms. The new era was hailed as the age of science, so the French scientists took the earth as their prototype and divided its meridian quadrant into 10,000,000 parts, one of which they termed the meter. Not being able to reach the North or South Pole, they shot the sun simultaneously at Dunkerque in France and Barcelona in Spain and computed the difference to be 9° 30′ of arc. It took seven years to survey the Dunkerque-Barcelona line, and we now know that errors crept into the calculations. The computations were revised in 1927, and the standard meter was then defined thus:

> The unit of length is the meter, defined by the distance at the temperature of melting ice between the centers of two lines traced on the platinum-iridium bar deposited at the International Bureau of Weights and Measures, and declared prototype of the meter by the first general conference on weights and measures, this bar being subjected to nor-

mal atmospheric pressure, and supported by two rollers at least one centimeter in diameter situated in the same horizontal plane and at a distance of 572 millimeters from each other.

An alternative definition was later provided which sets the length of the meter at "1,553,164.13 wave lengths of the red light emitted by a cadmium vapor lamp" excited under certain specified conditions. This gets the meter down to an accuracy of one part in 10,000,000.

But the greatest service rendered by the French scientists was the abolition of the relationships 3, 12, 36, 220, 1,760, and 5,280; the decimalization, upwards and downwards, of the meter; and, next, the establishment of a relationship between linear measurement and the measures of volume and weight, which are also decimalized. Defining the weight of 1 cubic centimeter of water as 1 gram, and the volume of 1,000 cubic centimeters—a cube, that is to say, 10 by 10 by 10 centimeters—as 1 liter, ties the whole system of mensuration together and gives us an easy way to calculate specific gravity.

Since its inception in France in 1799, the metric system has been legalized and adopted by practically every country in the world except those of the United States and the British Empire. True, one still finds in some of the South American countries the Spanish yard or "vara" of 42 inches in occasional use, just as one finds Spanish names for the coinage still used, although they have been proscribed for over a hundred years. In Venezuela it is confusing to have the quarter of a bolivar called a "media," but that is because they still call half a bolivar by the old proscribed name of "real."

When American mining engineers go to Venezuela—and practically all mining graduates from the United States spend at least one two-year contract in South or Central America—they remark on this little bit of evidence of the ingrained conservatism of the human race and think of it as a purely Latin idiosyncrasy; but they fail to notice the mote in our own eye. Similarly, we think the British method of stating a man's weight as "9 stone 3" cumbersome in comparison with our "129 pounds," and yet we continue to give our height as "5 feet 8." We have changed the definitions of many of the British measures while retaining the names.

Making a hundredweight 100 pounds instead of 112 is at least a move toward simplification, but why we have changed the gallon from 275 to 231 cubic inches or set the bushel at 2,150.42 cubic inches for internal trade, 2,747.715 cubic inches for export and import, and 2,564 cubic inches in Connecticut only, are matters not even mentioned in the laws establishing those standards.

For fifty-three years the meter has been our *legal standard* in these United States. It has been adopted for all scientific and technical measurements. Isn't it about time that we broke with the strong right arm of King Henry I and adopted a universal metric system?

The Metric System in Civil Engineering

MANUEL ZENO

UP TO the year 1898 the only official system of weights and measures in the island of Puerto Rico was the metric. In that year the island became a possession of the United States as a result of the Spanish-American War.

The American authorities promptly put into use the English system, and by 1913 it was made legal by an act of our legislature which provided that "the metric system of weights and measures and the imperial system commonly used in the United States . . . are hereby recognized and established as official in Puerto Rico. . . ." As a result everybody, from government officials through factory technicians down to the common citizen, makes indiscriminate use of both systems.

Now we have in Puerto Rico a "mixture" system of weights and measures. For instance, building lots are bought by the square meter, but houses are planned by the square foot; roads are measured in kilometers, while heights of our mountains are given in feet; water storage tanks are computed in gallons, but water is sold to the consumers by the cubic meter; temperature of the atmosphere is measured in degrees Fahrenheit, but the centigrade scale is used for body temperature. There are many more similar incongruities of this kind.

The Institute of Engineers of Puerto Rico has under consideration a proposal to organize a campaign in favor of general adoption of the metric system. The field is being canvassed in order to determine what inconveniences or obstacles would be encountered. While at this writing it is too early to reach any definite conclusions, it may be said that so far the consensus of opinion is in favor of the metric system.

Some authorities are quite emphatic. For example, the Commissioner of Health, Dr. Antonio Fernos Isern says: "My opinion is clearly and simply that the metric system is one of the conquests of civilization and consequently Puerto Rico, which adopted it officially many years ago but has been substituting for it in many spots antiquated, inconvenient and unscientific units, should cleanse its system of weights and measures and definitely accept the metric exclusively."

Engineer Orlando R. Méndez, Commissioner of the Interior, after explaining that the inconveniences in metric adoption arising from our close relations with the United States are more apparent than real, ends up by saying: "I decidedly favor the adoption of the metric system in Puerto Rico." Méndez emphasizes the fact that all Latin American countries use the metric system and have no trouble in dealing with North American manufacturers because they are careful to convert English units into metric in their transactions.

The Institute of Engineers of Puerto Rico will be able to make proper recommendations in due course of time, after it has had the opportunity to obtain opinions from all affected sectors. The writer is all for metric. He believes that we ought to shake off as soon as possible the weird, hybrid system that haunts our minds when we make computations in this island of the Caribbean Sea.

The Metric System in Automotive Engineering

SOCIETY OF AUTOMOTIVE ENGINEERS

DECIMAL dimensioning, affording major benefits of the metric system without simultaneously creating wholesale disruptive conversion headaches, increasingly is being used by the American aeronautical industry.

Survey by the Aeronautical Drafting Committee of the Society of Automotive Engineers, made among airlines operators and manufacturers of planes, powerplants, propellers, and accessories, discloses that 80 per cent now employs decimal dimensioning or contemplates its early adoption. Users explain that the practice of expressing limited measurements in decimals rather than fractions of inches contributes to speed and to accuracy both in design and in manufacture. Decimals are carried to two, three, or more, places to satisfy varying tolerance requirements.

The survey reveals that 76 per cent of the aeronautical industry has considered the use of decimal dimensioning, that 63 per cent uses it already, and that 37 per cent is using it for some purposes. In the propeller branch of the industry, 80 per cent of manufacturers uses the decimal dimensioning system exclusively.

The practice is characterized as making the dimensioning of drawings much easier and more rapid and as being especially helpful in eliminating the time-consuming, error-producing operations of converting decimals to fractions and back to fractions again. Furthermore, tolerances may be indicated merely by extending digits after the decimal point.

Manufacturing and Merchandising

The Metric System in Metalworking

THEODORE H. MILLER

THE metalworking industries in particular in this country have not made so much progress toward the use of the metric system as have some other fields, largely, I think, because of the mistaken idea that the changeover would be very costly. There is a constantly increased use of metric units in the chemical and drug industries, in electrical production, and in astronomy and almost all other scientific work. Besides this, a great many food products are put up in metric units or have the metric equivalent shown on the containers. All these activities have quickly shown the benefit of doing away with common fractions in favor of a decimal system. This has been true also in a few of the metalworking establishments of the country, where it has generally been found that the current saving is enough to pay for the cost of changeover and that the change usually has been very much easier than anticipated.

I was taught, and for many years used, the English system exclusively, but having now had almost forty years of designing and manufacturing complicated mechanical equipment on a rather large scale, I can testify that the cost of a changeover will be very slight compared with the eventual savings and that the expected difficulties of training help, and so on, will vanish into thin air on trial. In the plant where I have had this experience, many thousands of new mechanics and unskilled persons have had no difficulty whatever in mastering the metric system insofar as they needed to do so. Anyone capable of handling our money system can grasp the idea of metric measures within a few minutes; and from that point on, the change results in pure gain.

I feel quite certain there is no possibility that any of the countries now using the metric system will ever go back to the common fractions and complications of the English system. It would seem to me the part of wisdom for us to get in line as quickly as possible if we wish to trade with these countries. Certainly now is the time to make a decisive move.

The International System in Research and Development Engineering

ARTHUR BESSEY SMITH

INSTEAD of the term *metric system* I am using the term *international system of weights and measures,* because I include in that category the centigrade thermometer.

My work has been in the telephone industry from about 1892 to the present time. My experience includes most phases of plant construction, plant operation, manufacture, teaching, research (pure and applied), and ordinary development. For the past thirty-eight years I have been with the Automatic El[illegible]ic Company of Chicago, well known for work in automatic telephony.

It was in 1911 that I started to use the international measures in all my work. It was in the design of apparatus that I noticed the greatest change. Use of international units produced a feeling of relief, a sense of freedom which must be experienced to be appreciated. This experience forever settled the matter for me.

The natural thing to do is to use the international system. Daily use is the real test. The few basic measures in the metric system will be easily learned. Millimeters, centimeters, meters, kilometers follow each other in easy decimal relations. Grams, kilograms, and metric tons are equally easy, as are the milliliter, liter, and cubic meter. Forget conversion tables and factors and use the metric system wherever you can.

Take the mental position of a person living in a metric-using country. Carry a metric scale, estimate distances, verify them. Lift 500-gram and kilogram weights, and so on, and remember how they feel. Use 1-liter and 500-milliliter measuring cups.

As you progress in the use of the system in your technical work and around your home, you will appreciate the one uniform notation which expresses the smallest to the largest dimensions. There is no mixture of units. The decimal nature of the metric system is not the only one of its advantages which facilitates all work. Just as important is the logical unity which prevails among all units in all branches of science and engineering.

Though you do not memorize entire tables of conversion factors, before long you will begin to notice some recurring numbers. One millimeter turns out to be nearly 0.040 inch. Four hundred and fifty-four grams equal 1 pound avoirdupois. The metric ton is about the same as an English long ton. Three hundred and five millimeters make about 1 foot. The board 20 millimeters thick turns out to be an inch board dressed on both sides.

As to temperatures, it is well to memorize a few landmarks of centigrade readings. They are few and easy. At zero water freezes. The standard temperature for houses in winter is 20° to 21°. The standard temperature of the human body is 37°. Fifty-five degrees is about as hot as coffee should be. At 100° water boils. Five hundred degrees is a dull red heat. Fifteen hundred degrees is the temperature of molten iron.

Four systems of drills are in use in this country: the numbered series, the lettered series, common fraction inch, and metric. I prepared a few tables of the diameters of all drills except the metric. Every mechanic, especially if he is a machinist, has tables converting all the diameters into thousandths of an inch. I have just as much justification for having conversion tables expressed in millimeters. Several gauge systems are in use. The Brown & Sharpe, Birmingham wire, new British standard, and United States standard gauges are about all that the usual worker needs. I prepared tables of these in terms of millimeters. The regular system of iron pipes with Briggs threads uses common fraction inch names. But the dimensions are not always true, and we need exactness. The inside diameter of the so-called 1/4-inch pipe is not 6.35 millimeters, but 9.14 millimeters. Even the so-called 1-inch pipe has an inside diameter of 25.52 (instead of 25.4) millimeters. So I prepared tables of the precise sizes of these pipes in metric units. For laying out mechanical designs to scale I found that the Keuffel & Esser No. 1655 triangular boxwood scale is very helpful with its six scale ratios.

It paid me to set up a mental boundary at the edge of my laboratory or shop. When data came in from the outside in English measures, I converted them to metric. Inside my domain all work was done with the international units. Then when my results went out, dimensions were converted to English units. For some of this converting the Lufkin No. 8624 folding rule works very well. It has inches on one side and millimeters on the other. There is another rule, the Victor zig-zag No. 304-M, with the same scales. When I go out into the plant or into my own home to take measurements, I always take them in millimeters. When you do some woodworking around your home, like putting up a shelf or repairing the steps, the millimeter is the smallest unit which it pays to use. You can hardly saw a board any closer than to the nearest millimeter. Thus there are no fractions. Even in metal work on small parts, such as are used in telephony, the hundredth of a millimeter is the smallest unit needed, and it is decimal. As you work with millimeters, you will notice the frequent occurrence of such numbers as 6.35, 8, 9.5, 12.7, 16, 19, and so on, which are only equivalents of certain fractions of an inch which you will memorize just as you did the familiar fractions.

For the cross-feed screw of a lathe, graduated to thousandths of an inch, I have prepared a table.

LATHE REDUCTION TABLE

Mm	*Scale*
0.05	1
0.10	2
0.15	3
0.20	4
0.25	5
etc.	

I regard the graduations merely as numbers. If my calipering of the diameter of a piece indicates that I need to reduce it 0.15 millimeter, I merely turn the cross-feed three scale divisions, and thus I proceed for any reduction of diameter.

I handle the tail stock in a similar way. I can turn it to quarter turns with fair accuracy.

TAIL STOCK

Mm	*Turns*
0.4	0.25
0.79	0.5
0.19	0.75
1.59	1.0
1.98	1.25
2.38	1.5
31.75	20.0

If I am drilling a piece of work held by a chuck in the spindle, I can drill the hole to any reasonable depth by turning the tail stock the indicated number of turns. I have made out the table for tail stock as far as 31.75 millimeters, which is the equivalent of twenty turns.

Commercial tolerances are easily memorized. Our rough tolerance is 0.010 inch, which is 0.25 millimeter. The finer tolerance is 0.002 inch, which is 0.05 millimeter.

The end of my thesis is the same as the beginning. Use is the test; use will prove the worth of the system. Theorizing does little good. In the case of any earnest worker who can control his tools, and of any of us in working around our homes, a little careful thought will overcome any apparent difficulties. The rewards are for those who look for opportunity and venture to improve.

One System

J. E. HANSEN

IN THE porcelain enamel industry, with which this writer is most intimately familiar, we acknowledge the advantages of the metric system—and at the same time cling to remnants of the avoirdupois-feet system.

Raw materials are purchased by the ton or pound; formulating ingredients are supplied by the pound and are packaged in units of 50 or 100 pounds. Processing formulation is usually on a basis of 100 parts of basic material (frit) plus various percentages of added ingredients. This works very well until we get down to additions of less than 1 per cent, when we encounter fractions of ounces and thus fall back on metric weights to solve the shortcomings of a counter scale or balance calibrated in pounds and ounces. An example hardly needs elaborate explanation:

Mill Formula	*Weight*
100 pounds #ABC frit	100 pounds
7 per cent Enamel clay	7 pounds
2 per cent Opacifier	2 pounds
0.25 per cent Magnesium carbonate	4 ounces
0.20 per cent Sodium nitrate = 3.2 ounces	91 grams
0.02 per cent Tetra sodium pyrophosphate = 0.32 ounces	9 grams

Obviously, much less calculation and a smaller chance for error would be involved if we "went metric all the way."

In the porcelain enameling branch of the ceramic industry we have "gone metric" to the extent of expressing specific gravities of slips in metric units (for example, specific gravity 1.82) rather than in ounces per pint, but since ounces and the usual fractions thereof do not accurately enough express weights of application in processing specifications, we revert to grams per square foot.

Imagine the calculations required on the part of an accountant in checking the theoretical cost of the enamel on a part 17 inches wide and 23 5/8 inches long if the material is applied at 38 grams weight per square foot and costs $0.0837 per pound avoirdupois!

Need we say more to support the advantages of a metric system in porcelain enameling practice!

The Metric System in Merchandising

H. I. KLEINHAUS

WHEN most people use the term *merchandising* they generally refer to the series of human endeavors which culminate in consumer purchases. The great mass of consumer purchasing is done by women. Almost all consumer purchasing—even the selection of the home, the family car, and clothes for men—is greatly influenced by women's opinions.

Most women seem to detest anything which is related to mathematics. They usually take the butcher's word when he says, "Fifty-six the pound. That's 2 3/8 pounds—$1.33, ma'am"; and when they have returned home they despair of checking the butcher's computations because of the "frightening fraction." On the other hand, had the butcher said, "One kilo and eighty at $1.23—that's $1.33," there would be no "frightening fraction" but a simple problem in multiplication. In fact, a cash register-computing machine might throw out a receipt which would show 1.080 at $1.23—$1.33, and there would be no homework shopping audit at all.

The decimal system has been employed for years at the gas station, automatic cost figures based on gallons and tenths being clearly indicated to the purchaser.

In the department store field there are countless transactions made daily on the basis of linear measure. Yards and yards of dress materials, sheetings, shirtings, linings, and towelings are sold daily in many individual transactions involving fractional yards. Similarly in the notions department, in floor coverings, in ribbons both sales people and customers have the fraction to contend with. In more than half the cases the transaction requires, besides the ordinary multiplication of whole units and price, a division of price by the denominator, then another multiplication of the quotient by the numerator, and finally an addition of the two products previously obtained. The use of the metric system would obviate all the calculations save one multiplication of the amount, expressed in whole numbers and decimals, by the price.

Aside from these advantages of the metric system to customer and sales person there are others which produce direct economies in merchandising operating costs. This statement refers to the myriads of calculations involving fractional pounds and fractional yards which must be performed daily in a mercantile establishment, either wholesale or retail. Most of these transactions are accomplished by reducing the fractional parts of the unit to decimals, thus going through an additional step. Usually this step consists of glancing at a conversion table, which indicates the nearest decimal equivalent. But in this very step there exists a considerable chance for error. Only after the conversion is made can the computation be continued with the aid of a calculating machine.

The use of the metric system, however, provides a definite short cut in calculations involving fractional units of weight, size, and capacity. Tables for converting ounces to decimal parts of a pound, pounds to decimal parts of a ton, inches to yards, and so on, are no longer necessary. The size or the weight expressed in the metric system—meters and decimeters, kilometers and grams—could be set directly into a calculating machine, saving time through the elimination of a step and through that elimination also minimizing the chance of error.

From Letters to the Metric Association

THE NATIONAL ASSOCIATION OF RETAIL DRUGGISTS

THE National Association of Retail Druggists, one of the many organizations in the United States which for over a quarter of a century have favored a change in the system of weights and measures to obtain metric standardization, says in a letter written to the Metric Association:

> In so far as the cost of changing to the metric system is concerned, will say, that it would not be expensive.
>
> J. W. Dargavel
> *Executive Secretary*
>
> June 17, 1946

HARDWARE MERCHANT

Ask anyone you know who sells twist drills, files, hammers, hammer handles, hack saw blades, paint brushes, almost any hardware items that are packed and priced "per dozen"—even shoes, shirts, gloves, hosiery, etc. what a *nuisance* it always is to divide the invoiced price by 12 and at inventory time to reverse the process by counting per package then multiplying by 12 on so many, many items.

L. H. Zintgraph

Tampa, Florida
March 25, 1946

GENERAL ELECTRIC COMPANY

Personally, I am very much in favor of the change [to the metric system], even though it may involve considerable time, expense, and possibly some confusion. Whatever it costs will certainly be worthwhile.

I might add that this movement is far-reaching in that we are simplifying measurements for future generations. It may mean more work for ourselves, but we can consider it a contribution to the welfare of mankind. No doubt there will be some immediate benefit, but this is secondary in importance.

H. F. Hathaway
Apparatus Department
Washington Office

June 26, 1946

HART SCHAFFNER & MARX

We feel that universal use of the metric system would be beneficial to all. It is the writer's personal belief, however, that this should be approached by starting with our public school system. Those educating the younger generation to this line of thought would save a great deal of difficulty in future years of educating the older head.

Comptroller

July 24, 1946

Reply to a Questionnaire on the Metric System

MERCK & COMPANY, INC.

I HAVE been asked to reply to your inquiry regarding your survey of public opinion on the use of the Metric System. [See page 156.]

No one is better acquainted with the unnecessary difficulties that are constantly met with due to lack of uniformity in systems of weights and measures than a company engaged in scientific and commercial endeavors that are international in scope. The business of Merck & Co., Inc., at the present time necessitates the use of one set of weights and measures for ordinary domestic usage, i.e., American pound, gallon, etc.; another set, the apothecary system for pharmaceutical usage and a third set of the Metric system for its scientific work. In addition to this, the international character of the business requires a knowledge of English and Continental weights and measures.

I am convinced that it would be of the utmost advantage to the United States to use Metric weights and measures in manufacturing, buying, and selling, in trade and in all educational endeavors. It is probable that the adjustment required could be made within ten years without any great inconvenience and it might seem best to effect the change by legislation.

C. R. Addinall, Ph.D.
Director, Technical Information Department

January 26, 1937

Medicine and Pharmacy

The Metric System in Medicine

AUSTIN SMITH

THE practice of medicine consists essentially of preventing and diagnosing illness and treating the sick. The administration of potent drugs is an important part of the treatment, and the use of an easily and universally understood standard of measurement facilitates the administering of drugs and minimizes the possibility of error. The metric system provides such a standard.

The Council on Pharmacy and Chemistry of the American Medical Association has advocated the adoption of the metric system and on several occasions has published statements explaining why it believed that this system is the logical one to use in medicine. For several years the Council has used only the metric system in its publications, including *New and Nonofficial Remedies.* It also has encouraged this method of standardization by participating in conferences with other groups interested in this problem, and from one of the conferences there has come a joint recommendation by the Council on Pharmacy and Chemistry, the Office of the United States Pharmacopoeia, and the Office of the National Formulary calling for the exclusive use of the metric system by the medical, pharmacal, and allied professions, and by the drug and pharmaceutical industries. As a result of this consideration the United States Pharmacopoeia and National Formulary will list dosages in the metric system, followed, at least for the present, by equivalent apothecaries' dosages, which will be set in parentheses and will be only approximate. Thus the declared amounts on the drug labels can be stated exactly in the metric system and can be used as the basis for control tests. This procedure is quite acceptable to the Food and Drug Administration.

The advantages of universal adoption of the metric system are many. In medicine the advantages include accurate manufacturing, accurate prescription writing, accurate compounding, and accurate administration of drugs. The control departments and research departments in the drug and pharmaceutical industries much prefer to use metric measurements; the physician and pharmacist can write and interpret directions with mutual confidence; and the physician can determine the dosage for the individual patient with much greater ease. For example, he can use whole numbers when determining the amount of drug needed on the basis of the body weight of the individual, and he can obtain a better appreciation of the distribution of the drugs throughout the body when he examines metric reports on concentrations of the drug in the urine and blood. The sulfonamides used for infections and thiocyanates used for hypertension are just two examples of the drugs that are followed closely in this manner.

Over a long period of time, members of the House of Delegates of the American Medical Association have repeatedly recommended the use of the metric system by the medical profession. In fact, in 1878 a resolution was introduced and passed in the House which recognized the value of this system and ". . . recommends to all physicians the use of the same in their practice and in their meetings and teachings." It is unfortunate that not all physicians have fully adopted this system, but with the passing of each year more physicians are using it. This is especially true of the younger men.

The Council on Pharmacy and Chemistry adopted the metric system because of the occurrence of serious accidents in administering prescribed doses of drugs which resulted from confusion between the metric and apothecaries' systems. It would have eventually taken this action without such practical stimulus. The Council recognizes that the universal adoption of the metric system would be a manifestation of rationality and of interprofessional and international cooperation of high practical utility. When the Council announced its intention of exclusively using the metric system in its publications, including books, a member of the engineering profession enthusiastically endorsed this action. He wrote, in part: "The metric system represents a standard which can be used and understood in every civilized country by every profession. It is one of the few scientific things that practically all professions can have in common. . . . The engineering profession stands to gain as much as the medical profession from the general adoption of the metric system."

Similar support is needed from other professions if the metric system is to be adopted for general use in this country and if in respect to health we are to be on common ground in the scientific and business fields with other nations. If all kinds of service and industry adopt the metric system, confusion and misunderstanding will be lessened.

[Editor's note: The medical profession has now made a move which could and should be followed by the grocers' and canners' associations: the placing on canned goods of metric labels with the English equivalents in parentheses. At present there are double labels, but the metric amounts are subordinate.]

Universal Use of the Metric System in Medicine

MARTIN H. FISCHER

MUTUAL understanding arises among men when like sounds come to convey like meanings. This is why music is the most universally understood medium of communication, and why a common language is the next best.

In science the common bond among weights and measures is the metric system. This is now the *only* language of measurement spoken in the largest portions of this earth and by the largest number of its people. Metric standards prevail everywhere in the world except where Britain or the United States holds sway, and even in these countries advocates of the metric system have long been active on its behalf. What scientific worker in these countries has dared perpetuate the jargon of yards, quarts, and ounces, unless he lacked the true scientist's desire for precision? The British Empire and the United States have injured themselves by persistence in their ways. Perhaps it is too much to charge that British biological discoveries were not more quickly known to other countries merely because they were expressed in measures no longer familiar to the rest of the world, but it is legitimate to say that much international trade has been lost to both the British Empire and the United States through discrepancies in measurements of manufactured goods. Although buyers in South America and Russia, for example, may not subscribe to political philosophies pleasing to us, they are good potential customers, and they do business in metric terms.[1] On this account they have long preferred to turn to Germany, Austria, Switzerland, Sweden, Holland, France, or Spain instead of to the United States in placing their orders.

Six years of war have not changed this fundamental psychological factor. These wartime experiences, however, may be thanked for having *compelled* the British Empire and the United States to give fuller consideration to the almost universal metric system. For our joint military efforts in Europe and the Pacific, makers of equipment saw the job through the metric way in designation of gun bores, toolings, railroad parts, and elevations. But even this gain, it may be feared, will not endure in peacetime. As a machine tool manufacturer said but yesterday, "The toolers work on hundredths of an inch, with the British inch two-thousandths longer than our own. Inch hundredths reduce all metric denominations to bastard sizes, with the conversion equivalents never on the line." This situation may continue despite the facts that for aviation the international sky is today laid out (even for us) both up and across in kilometers, that the earth's surface is laid out in hectares, and that the working of the flying thing itself is measured in terms of ergs.

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[1] Recently an Italian priest asked his sister in the United States to send him a few Roman collars (size 39 centimeters) with yokes (size 47 centimeters). The local mathematicians had to work out these values to mean 15.354 inches for the former and 18.504 for the latter. The materials were then dispatched in the United States standard sizes 15 1/2 and 18 1/2.

Compulsion of the doctor in the United States to think in metric terms may be cited as another bit of good extractable from six years of war. The cabalistic notations of the American doctor began to blur even to his eyes fifty years ago; the physicians, pharmacists, and drug manufacturers started to write the metric equivalents opposite their minims, grains, scruples, and drams. Why the better designations did not at once displace the poorer can be explained in several ways, but only two points need be noted. (1) The apothecaries' system was the one taught in the schools; (2) the graduates and practitioners could not be trusted to convert into terms of this system orders given in the international metric units. There were constant opportunities for error. "A pint is a pound the world around," but how about an ounce? Many people (especially those versed in Latin) know that *ounce* means "the twelfth part"—but of what? To the drugstore clerk it is the *twelfth* part of the *troy* pound (480 grains or 31.08 grammes), but when he buys wholesale it is in *avoirdupois* pounds each of which contains 16 ounces (437.5 grains or 28.349 grammes).

That spelling of *gramme* is a carryover from the last century, when it was insisted upon by the scientific doctors, physiologists, and pharmacists of the day so that errors which would make medical horror tales might be avoided. If the *i* in *grain* is not dotted, the word looks like *gram,* which in conversion multiplies the amount by 15—a result which is rather bad if morphine, atrophine, or "bichloride" is the material ordered. And what have sometimes been the consequences when an attempt has been made to translate simple percentage solutions intended for injection or wound treatment into the weird multiples of grains to the ounce?

It is a pleasure to report that within this decade the former ratio of apothecaries' to metric measures in written prescriptions has been increasingly reversed. The desired dose is more and more called for first in metric terms and then in the terms of Britain and her dominions and of the United States and her territories.

There is still better news. I have before me the catalogues of several American chemical and pharmaceutical manufacturers who list their products in metric terms *only!*

The homegrown standards of the British Empire and the United States (along with their trade practices that make imperial, standard, and other gallons all different units, and pints, pounds, and ounces highly variable) seem to be on the way out, as they ought to be. Our medical officers during the war were first surprised, then baffled when they met foreigners, whether friends or foes, who spoke in metric terms; but they learned. Those who returned from service overseas now speak only of cubic centimeters of blood, milligrams of drugs, alkaloids, and vitamins, and grams of protein. They do not wish to return, and it is to be hoped that they will not return, to variable quarts, pints, or ounces. Before the war they could argue that they dared not use the metric system because our pharmaceutical manufacturers, pharmacists, nutrition experts, and farmers did not know what it stood for. Now, however, a new generation is rising. Governmental, professional, and agricultural leaders seem increasingly inclined to accept metric units. A recent government report (one of a hundred on nutrition) argues the relative merits of standard, enriched, and whole wheat flour by printing the milligram amounts of their several vitamins upon the outline of a sack.

The swing is evident. Those in authority are asked to hasten what is inevitable.

Metric and Avoirdupois in the Drug Industry

EDWARD V. MEITH

EVERYONE, I believe, is well acquainted with the fact that all scientific laboratory instruments, such as pipettes, burettes, flasks, beakers, and graduated cylinders, are marked and identified by metric sizes. The foundation of pharmaceutical and biological manufacturing is research carried on by the use of such instruments in the laboratory. Here drugs and future medicinal products are conceived and tested for possible toxic reactions, physiological action, and potency. Usually the research chemist is dealing with relatively small amounts of material; at times, even, these amounts are really minute, almost microscopic. To work precisely and within the scope of the apparatus available, the chemist must measure these small amounts in units of the metric system. I believe I can say with positive assurance that everything concerned with the research chemist's work is measured by the metric system. All of his graduated glassware is metric; his fine balances, scales, and weights are metric.

One of our first steps in pharmaceutical manufacturing is to write up the formula for any given product. Included in this formula are the exact amounts of each ingredient, plus all steps required for manufacture of the completed item. The aforementioned amounts are, with very few exceptions, recorded entirely in terms of the avoirdupois system: pounds, ounces, fractions of ounces, and grains. After the product has been manufactured, it goes to the filling department. Here we encounter filled weights which are a mixture of avoirdupois and metric units. The majority of these weights, such as those of powders and powdered extracts and ointments, are expressed in pounds and ounces. However, a considerable number of special items and ophthalmic ointments are filled in units of the metric system.

Let us go back to the steps immediately preceding manufacture. Raw materials used in large-scale manufacture of pharmaceutical products come from many faraway places on the globe. Among these are ergot from Spain, parsley and caraway seeds from South America, gentian from southern Europe, rhubarb from

China and Russia, licorice from Turkey, and vanilla beans from Madagascar. Besides the foreign imports, a very large percentage of raw material used comes from domestic markets. Here, to my mind, exists the greatest paradox of all. We order quite a number of fine chemicals from companies right here in our own "avoirdupois country" which are handled in units of the metric system. Some of these we order in kilograms. On some occasions when we have placed an order for a material for use in a new product, we have been faced with this complication: We ordered so many pounds of a given item. Upon checking the shipment, we find it supplied to us in kilos. The goods will be invoiced to us at so much per kilo. In order to check our cost records, the invoice must be converted to price per pound, and the receiving department must either convert the actual package weight from kilos to pounds or have scales available to weigh by both systems.

After having been received, crude drugs and chemicals are assigned to one department, known as a drug and chemical stores. The newly arrived items, after being carefully checked and assayed, are then entered upon the records of this department. If the items were ordered and received in units of the metric system, here again they must be converted to pounds and ounces.

For each lot of any product manufactured, a copy of the original formula is issued. Arriving at the correct proportion of all ingredients can be quite a complicated problem. Each ingredient must account for a specified percentage of the finished product. Figuring all these percentages in units of the metric system would be much easier and would allow less chance for error than the complications which arise from use of the avoirdupois system. As an example of this, I would cite tablet manufacture. Since raw materials are stocked and recorded in pounds and ounces, as we have seen, the ingredients in the formula are figured in avoirdupois units. If a lot of 5-grain tablets is to be manufactured, the formula is made up for some multiple of 7,000, such as 35,000, 70,000, 140,000, and so on. Two and one-half grain tablets would be figured in lots of 17,500, 35,000, 52,500, and so on. This procedure is practically a necessity in the figuring of large lots of ingredients in avoirdupois weights. It is very easy to see how much simpler all this would be if the metric system were universal.

In 1921 Dr. Frederick Banting, a pioneer in modern medicine then twenty-eight years old, began experimental work at the University of Toronto to develop a treatment for diabetics. The result was insulin. This product is an outstanding example of a fluid item which is made up by weight in units of the metric system. The highly concentrated solution of the active extract from beef and pork pancreas glands is delivered to a dilution department as an amount weighing so many grams. Here the extracts are prepared and diluted with suitable solvents and precipitants for therapeutic use. This process is carried on in large tanks mounted on scales weighing by the metric system. All the weights of the aforementioned solvents and precipitants are written on the formula ticket as so many pounds, ounces, and fractions of ounces. Following these figures, in parentheses, are the metric equivalents. The ingredients added to the pancreas extract are ordered from outside sources and stocked in units of the avoirdupois system. The metric equivalents must appear also, because the basic extract is supplied in grams, and the entire process is completed in the metric system. The finished insulin is finally filled and marketed in ampoules of—usually—5 and 10 cubic centimeters.

Nearly all medicinal products sold which are labeled as weighing so many grains or ounces also bear the metric equivalents. Liquids usually bear ounce or pint labels with cubic centimeter equivalents.

Even the marketing of pharmaceutical and biological products runs afoul of the avoirdupois-metric situation. Domestic shipments can be marked with gross, tare, and net weights in pounds. But foreign shipments, particularly to South American countries, must be declared to customs officials in kilos. The net weights on these shipments mean *just that:* the weight of the *material* only, not of the small glass ampoule or tiny carton, any number of which might be packed in a shipping box. From final inspection checks of tablets, we can get the weight of 100 tablets in grains. All the previous manufacturing steps have been made in avoirdupois weights; so, of course, must the final inspection checks. This weight then must be converted to kilos for each size of tablet bottle, of which there may be five or six. Now, as you can see, if the metric system had been followed throughout the entire manufacturing process, all this converting of figures and weights at the end of the line would be totally unnecessary as far as foreign shipments are concerned. However, if the drug trade alone switched to metric weights entirely, then domestic shipping weights would have to be converted from metric to avoirdupois. Unless—and until—our country, and even the world as a whole, establishes a universal weighing system, some conversion of weight readings cannot possibly be avoided.

Doctors with whom I have talked do not have any great criticism for either system of weights. The one interesting fact I have uncovered about prescriptions is concerned chiefly with the sulfa drugs and their derivatives. Medical research and experience have indicated that the optimum dose of the sulfa drugs is governed by body weight, and so it follows that the dosage of the drug prescribed will, in so far as possible, amount to a predetermined percentage of the patient's weight. If this weight were measured in the metric system, the amount of drug to be administered could be arrived at much more easily and quickly.

Certainly a great many manufacturing difficulties in the drug industry would be resolved by the exclusive use of the metric system. However, until either the metric or avoirdupois method is used exclusively throughout this country and the world, commercial relations must recognize, and cope with the problems arising from the use of both systems.

Universal Adoption of the Metric System*

The End of Confusion Is Near Because the Recent Action of the AMA Opens the Way for Universal Adoption of This System

An editorial in a recent Journal of the American Medical Association pointed out the "great practical utility" of the universal adoption of the metric system. The medical profession, and its auxiliary health professions, including pharmacists, should carefully observe this growing trend.

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* Reprinted from the March, 1944, issue of *American Druggist* by special permission of the publishers.

Invention is frequently born of necessity. Individuals and tribes needed some means of appraisal of weight, and many minds contributed to the original invention. The traditional or natural systems of weights were based on various parts of the human anatomy or articles of common use. Lack of uniformity was prevalent; confusion common.

The origin of the metric system is relatively modern and completely rational. The meter, the unit of the metric system, is one ten-millionth part of the distance between the equator and the pole. It is immaterial what is adopted as the unit of a system, provided this unit is afterwards defined to become of fixed and absolute value. The standard meter is (or was!) kept in Paris. Other countries have prepared standard meters from the original, so if Hitler's hordes have destroyed it there are others available. The distance from the equator to the pole could be calculated again at any time, should this be necessary.

If pharmacists were asked what percentage of their prescriptions are written in the metric system, the answers would vary from fifteen or twenty per cent to well over fifty per cent. But the per cent has been slowly increasing with the younger medical practitioners, who are more inclined to use the metric system.

The universal use of the metric system in scientific works and its adoption for other uses appear to be good reasons for its use in medicine and pharmacy. In spite of the emphasis on the value of adopting a uniform method of presenting quantities and doses, the universal acceptance of the metric system has been slow. In 1799, France was the first nation to make the metric system obligatory. Many other nations followed. The United States, Great Britain, and Russia[1] are among the last important nations to place the metric system in use. Its use is legalized but not made obligatory by law in these nations, and in Egypt, Japan, and Turkey.

If physicians are to use the metric system in prescribing, they must be taught to think in metric terms because conversion of quantities into metric units may be compared to writing in a foreign language, and then laboriously translating it into English. The recent action of the Council on Pharmacy and Chemistry, of the American Medical Association, in deciding to adopt the metric system exclusively in its publications should hasten what seems to be the predestined universal use of this system of weights and measures. It should mean the employment of the metric system in medical teaching centers and in the preparation of papers for publication in medical journals.

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[1] Editor's note: The use of the metric system was made obligatory in Russia in 1921 and in Japan in 1922.

Many manufacturers label their products exclusively in the metric system, or in this system with an accompanying equivalent. Manufacturers of vitamins, hormones, sulfonamides, etc., have contributed to the universal adoption of this system by using it in labeling products, thus causing the medical and the auxiliary health professions to think more and more in metric quantities. Now, with the action of the A.M.A., it may not be a far step to the universal adoption of the metric system.

The Metric System Exclusively?*

THE Council on Pharmacy and Chemistry of the American Medical Association has recently announced that henceforth New and Nonofficial Remedies, Useful Drugs, the Epitome of the U. S. Pharmacopoeia and National Formulary, and Interns Manual (publications of the American Medical Association) will give quantities and doses only in the Metric System. It is hoped that this action will hasten the day when the Metric System alone will be used in pharmacy and medicine. The decimal system of fractions, together with the fact that every unit of weight, volume, or length bears a simple relation to the initial unit (the meter), makes the system easy to understand and manipulate. It has been used in the scientific field for years. The present practice of using two systems leads to confusion and, in some instances, to serious errors in prescribing and compounding. In a recent survey of four prescription pharmacies in Chicago, one reported that 75% of the prescriptions were written in the metric system, a second reported 70%, a third 40%, and a fourth 25%. A number of physicians used both the metric and apothecaries' system on the same prescription.

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* Reprinted with permission from the *Southern Pharmaceutical Journal*, January, 1944.

Hemispheric Solidarity and World Trade

Metric Standardization in Pan-American Trade

AUBREY DRURY

In this Atomic Age, in the face of the keenest commercial competition the world has ever known, our people—otherwise so truly efficient—cannot afford to hang on to Stone Age tools of trade, an obsolete jumble of weights and measures which the rest of the world will not tolerate. Particularly is this true of Pan-American trade, which ought to be unified forthwith if we are not to impede progress and embarrass our people's welfare. The country in which the headquarters of the United Nations and of the Pan American Union are established is not likely much longer to lag behind in this vital sphere of interest. Measurement is indeed the master art.

It is axiomatic that when commodities are offered for sale, they should be offered in terms which the buying public will understand. In marketing our products throughout Latin America, therefore, we shall be following the best merchandising methods when we quote in "the world language of quantity"—the decimal metric units. In all commercial transactions, the basic question is, "How much?" The answer should be clear and unequivocal.

These metric measures, uniform everywhere, enable the world's people to live, work, and trade together, understanding one another's quantity language. The dollarlike units are divided into cents and mills. There is nothing to misunderstand. It is little wonder that virtually all peoples have eagerly accepted these units as standard for world trade transactions.

The First Pan-American Congress, held in 1890 in Washington, D. C., laid the foundation for lasting friendship and trade between the Americas. One of the most important agreements, adopted unanimously, with the full concurrence of the United

States of America, declared, "The conference recommends the decimal metric system to the nations which have not already adopted it."

As a result of that conclusion, Mexico and all republics of Central America, South America, and the West Indies by legal enactment confirmed the adoption of the metric units. Our great Secretary of State, James G. Blaine—sponsor of the Pan-American conference plan, reviving the project of Simon Bolivar—urged favorable action in the United States likewise; but metric legislation was blocked by a narrow margin in Congress, and in this vital advance the United States lagged behind all the other American republics. Metric legislation, however, was never defeated in a general clear-cut vote in the Congress of the United States.

As a result of the movement then inaugurated, progressive commercial elements throughout the Americas have unified to secure the advantages of the decimal metric units for all. In accord with this program, the First Pan-American Standardization Conference (which met in Lima, Peru, in December, 1924, and January, 1925) took action favorable to metric standardization. By resolution it was urged "that the units of weights and measures in the various countries tend toward the decimal metric system." The United States of America, represented at the conference by an official delegation, was included in the recommendation. I am glad to have had a part in attaining that progressive action.

New specifications, and changes in those now existing, are to be in terms of the metric units throughout the Western Hemisphere as soon as the program of the several Pan-American Standardization Conferences is carried into effect. In the meantime, it is recommended that metric equivalents be used in catalogues and other commercial literature to aid transition to world-uniformity.

An appendix to the resolutions passed at the Lima conference specially urged the petroleum industry throughout the Americas to advance to the metric basis, using the cubic meter for measurement of crude oil and the liter or "world quart" for gasoline and lubricants.

Guillermo A. Sherwell, eminent Secretary of the Inter-American High Commission and official delegate from the United States to the First Pan-American Standardization Conference at Lima, urged the victorious metric action. Advocating adoption of metric units by the United States, he testified, "Use of the metric system would facilitate international commerce, and consequently favor the development of our national industries."

With striking unanimity Pan-American conferences which have considered the metric topic have declared that *all* American republics should standardize on the metric basis in merchandising. Among these may be cited the Pan-American Financial Congress, the Pan-American Commercial Congress, the Pan-American Scientific Congress, and the Customs Congress of the American Republics. Representatives of the Inter-American High Commission have appeared before the Congress of the United States and have attested their advocacy of the metric advance for the promotion of understanding and commerce throughout the Americas, and officials of the Pan American Union likewise have endorsed metric standardization.

As that eminent leader, the late Leo S. Rowe, Director General of the Pan American Union, said, "The United States loses business in Latin America because of persistence in using 'customary' weights and measures in exports which are not understood and do not fit in with the industrial economics of the Latin Americans. In effect, we are trying to sell left-handed tools to people who are right-handed."

On another occasion, Rowe wrote me, "I have examined at one time or another all the contentions of those who opposed the adoption of the metric system for general use in the United States of America, and I find no valid ground for the allegation sometimes made that the change will involve widespread loss and confusion. The change need not be made overnight; there will be time for adjustment of appliances in the industrial world generally; and time for the schools and the press to familiarize the public with the units and terminology of the metric system."

With Rowe's predecessor, John Barrett, I discussed metric standardization on several occasions. He, also, was a strong advocate of general use of the world-uniform units in the United States of America and in Pan-American trade.

In order to ascertain the value of the metric units of weights and measures in increasing the external trade of the United

States, as the director of the All-America Standards Council I addressed an inquiry to United States consular officers throughout the world. Out of more than one hundred replies received, it is notable that not one consular officer has reported adversely to the world metric standards. Virtually all are strong in their declaration that gradual adoption of the metric weights and measures will greatly promote our trade abroad. This unanimous opinion of world-trade experts is indeed eloquent "proof by authority."

The testimony coming from United States consular officers in Latin America is of particular value. That metric weights and measures are invaluable in gaining and holding the trade of countries on the metric basis is attested by this virtually unanimous opinion of the consular officials and commercial attachés of the United States abroad. They are trained observers, in a position to note the true value of the metric units in everyday transactions, and their strong approval of the metric measures indicates that these are truly successful in the countries where they are instituted and work well in practical affairs.

Further testimony as to the value of the metric units in the countries where they are used comes from the American chambers of commerce established there. Virtually every American chamber of commerce in other lands has urged that the United States likewise adopt the metric units to promote our export trade. The United States Chamber of Commerce in the Argentine Republic and the American Chamber of Commerce of Brazil are among the many organizations which urged the United States to get in line with the commercial practice of the world and to adopt the metric units for merchandising.

These chambers of commerce are made up mainly of American businessmen who are able to view the use of metric measures in actual trade transactions, and their unbiased testimony is some of the best that could be offered.

The Mexican Chamber of Commerce of the United States, Inc., with headquarters in New York City, some years ago declared that the use of metric weights and measures is of even more importance than the use of the Spanish language in securing trade, not only in Mexico, but throughout Spanish America.

Declaring that the most pressing problems confronting human-kind are economic and not political, George Prescott Blow, as Chairman of the Standardization Committee of the International Chamber of Commerce, made this significant statement: "I consider the topic of world metric standardization the most important question before the world today. Adoption of the decimal metric units by the United States of America will be the greatest commercial advance of the century."

This authoritative declaration was that of a man who made a lifelong study of standards in commerce and industry. As President, and later as Chairman of the Board, of the Western Clock Company (well known as manufacturers of the "Big Ben" family of clocks), he became recognized as one of the foremost leaders in American industry. He served as a member of the Board of Directors of the Chamber of Commerce of the United States and was influential in organizing the International Chamber of Commerce in 1920.

The memorable survey of the Pan-American trade field made by George Prescott Blow is thus recorded: "In 1914, just before the first World War began, I made a voyage down the eastern coast of South America, passing through the Straits of Magellan, up the western coast, and then home via Panama. I took pains to study the trade conditions on both the Atlantic and Pacific coasts, and returned convinced that the principal (if not only) reasons why the Germans were driving out American and British goods, of a better quality than those they supplied, was because the Germans and South America both bought and sold, advertised and talked in the same trade language, '*metrics*'; while we had to translate into a 'system' they had long ago forgotten. I was called before the (then new) Federal Trade Commission, in Chicago, and gave my opinion and conviction to this effect." [1]

World War I taught inescapable lessons as to the urgent need for world unification of standards in commerce and industry, as well as in warfare. Closely allied with manufacture and industrial efficiency is invention. As was so well pointed out by Samuel W. Stratton, metric standards, being exclusively used by those engaged in scientific research and invention, should likewise be employed throughout industry in order that the results obtained may be *quickly transmitted into factory production.* It has been proved that without the metric measures the development of such industries as the electrical, radio, and aircraft industries would have been virtually impossible, because progress came only through the accumulation of data in the metric units by researchers in various countries and the rapid transmission of the results of this research in understandable form to collaborators elsewhere.

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[1] Aubrey Drury and others, *World Metric Standardization* (World Metric Standardization Council, San Francisco, 1922), p. 506.

Our industry owes an unpayable debt to American inventive genius and should heed the advice of the inventors who have so strongly pleaded for the adoption of the metric standards. Alexander Graham Bell, inventor of the telephone; George Westinghouse, inventor of the air brake; and Elwood Haynes, prominent in the development of the automobile, personally appeared before Congress and urged adoption of the metric measures. Thomas A. Edison, the world's greatest inventor, was an advocate of the passage of metric legislation. From him I received many letters urging this progress. His noted sons share his interest in this cause.

That there has now come an awakened public recognition of our duty, to ourselves, to Pan-America, and to the world, is indicated by the widespread public interest in the metric standardization movement throughout the United States. It is expected that a liberal metric standards bill will be introduced in Congress providing for a gradual transition to the metric units in merchandising. States with a total population of 20,000,000—Illinois, Tennessee, California, North Dakota, and Utah—are on record on this question through their legislatures, which memorialized Congress to pass such a law. For some years, more than 100,000 individual petitions have been pending before our national legislators urging the advance and altogether these represent millions of voters, for many petitions are from organizations having thousands of members.

Let it be emphasized that the proposed ~~metric~~ legislation will apply to *merchandising* only—manufacturers are to continue to use whatever weights and measures they desire in production, but after a transition period they are to buy and sell on the decimal metric basis. *This will not change the size of anything, but will merely be a modification in the terms of description.* Recognizing the ease and facility which this will give to the distribution of manufactured products, thousands of manufacturing concerns are among those favoring the passage of metric legislation.

As Albert Herbert, manufacturer and world trader, leader in the metric cause, so well said, "It is surprising that metric standardization was not brought about long ago. No one objects to it except a microscopic minority."

As a peace move, this metric advance will be of utmost value. No step could so greatly promote amity and understanding between the United States and all the other American republics. It would be a vital factor in inter-American defense; and above all it would develop trade, "that calm health of nations."

Andrew Carnegie, foremost industrial leader of America, declared: "The present weights and measures of the United States of America are unworthy an intelligent nation today." Andrew Carnegie strongly urged metric standardization. Benefactor of world peace, he was the main donor of the beautiful building of the Pan American Union in Washington, D. C.

By removing the toll bars that hinder free transmission of ideas, by facilitating interchange of commodities in world trade, the metric progress will confer manifold benefits.

To conclude in the eloquent words of Charles Sumner before the United States Senate: "Here is a new element of civilization which will be felt in all the concerns of life at home and abroad. It will be hardly less important than the Arabic numerals, by which the operations of arithmetic are rendered common to all nations. It will help undo that primeval confusion of which the Tower of Babel was the representative."

The Metric System from the Pan-American Standpoint*

WILLIAM C. WELLS

THE Pan American Union was created by a resolution adopted in the First International Conference of the American Republics, held in Washington in 1889. All the 21 independent republics of

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* Reprinted from *Scientific Monthly*, Vol. 4, March, 1917, pp. 196-202, by permission of the publishers.

North and South America join together in the support and maintenance of the institution, which [illegible] governed by a board consisting of the U. S. Secretary of State, ex officio, and the diplomatic representatives in Washington of the 20 Latin American republics. Its general purpose is to create and foster a larger commercial and intellectual intercourse between the republics of the American continents. It is an all-American institution interested in every question which does, or might, concern the two Americas, among which the question of weights and measures is not the least important.

If there is one thing in the future that can be predicated as a truth with more certainty than another, it is the changing position of the United States in respect to its foreign commerce. This change, while accelerated by the World War, is in no way a result thereof. It is due entirely to our own development, consequently creating a changed international commercial status for the United States. It is industrial evolution in its comparative relations.

Formerly our exports were of raw materials, primary food products, slightly wrought commodities—in fact, of those things wherein the larger commercial values were represented by the work of nature and the lesser values by the work of man. We were selling primarily the minerals from our hills, the trees from our forests, and in our cotton and our grain the fertilizing elements of our soils. We were selling for the most part the handiwork of nature and not of man. We were depleting our capital resources—but on the whole not at a loss. We were following the natural highway of evolution from the forest and mining industries to the pastoral, to the agricultural, and on to the mechanical. In a sense we were converting a part of our static capital into liquid capital.

In the last decade or two the character of our exports has begun to change. Measured by values, we are selling less of the products of our mines, of our forests, and of our fields, and more of the products of our labor and skill. Where we sold lumber, we are selling chairs, tables, and desks; where we sold pig-iron, we are selling knives, plows, and machinery.

It is not necessary to elaborate this idea. It must be apparent to everyone that we are coming to the point where our growing population will consume all our own food products, where our mills and factories will use all our own raw materials, and where our only surpluses for export will be the finished and highly wrought products of these mills and factories. This is as it should be, for thus we shall be selling for the most what man creates and for the least what nature creates. What has all this to do with the metric system? Much, very much.

Broadly speaking, all exports may be classed under two heads: first, such as sell themselves, that is, where the buying and selling machinery is for the most part put into operation by the buyer; and, second, such as must be sold; that is, where the machinery is operated almost entirely by the seller. These two classes correspond almost exactly with the two other classes first indicated above, viz., raw materials and primary food products, on the one hand, and finished and highly wrought commodities, on the other.

Cotton, wheat, flour, lumber, unwrought metals, oils, hides, wool, meat, and the like, sell themselves. Wherever in the world these things are needed and there is the price to pay, the buyer sets in operation the machinery to secure them. The farmer does not have to send out commercial travelers to sell his cotton. He does not have to advertise it in the papers. He delivers it to the railway, and there it is caught up by a machine in no wise his creation, which finally dumps it down at some factory door—where, the farmer never knows, it may be in Massachusetts and it may be in Italy. But for the factory that spins the cotton into yarn and weaves the yarn into cloth, it is another matter. This cloth does not sell itself. It must be sold, and its maker must find a market for it. The impulse begins at the factory; it follows through the broker, the wholesaler, the retailer down to the ultimate consumer. Cloth, knives, plows, and desks must be pushed from behind. They are not pulled from in front as are cotton, wheat, and pig iron.

It is here that we come to the point where weights and measures are important . . .

Our changing foreign trade demands a change in our customary measures. So long as we cling to our inches, yards, pounds, and gallons, we carry a weight, a useless weight, that of itself is sufficient to hold us back from that first place as an exporter of highly wrought manufactures which is ours by right of skill, enterprise, and resources.

The importance of the metric scale in foreign commerce even now presses hard upon us, and it will press harder and yet harder in the future. We must adopt the metric scale, because nearly all the rest of the world, save the British Empire, has adopted it, and this world is the market in which we must buy and sell.

Furthermore, we should adopt it because of its inherent merits, its vast superiority even for domestic use over our present system. I think I may say without fear of successful challenge that, while any intelligent child can learn and carry in his mind the whole metric system in three lessons, and any adult can master the same in one hour or less of serious study, no man ever has, and probably no man ever will, master the United States system of weights and measures. Personally, I would rather undertake to commit to memory the multiplication table up to the factor of 100 than undertake such a task as this. Take the case of bushels and barrels, measures upon which millions upon millions in values of products are bought and sold: there are scores upon scores of different bushels and hundreds upon hundreds of different barrels—customary, standard, and legal—in use in the United States.

The metric system is simplicity itself. It has many merits in nomenclature and in interchangeability from lengths to weight to volumes, but the chief merit to my mind is that it has the same base ratio thruout. Measures should have the same base ratio. That they have not is one of the principal inherent weaknesses of our English system as compared with the metric system . . .

All the civilized world counts by tens, and most of the world measures its money by tens. Compare our money values—10 cents to a dime, 10 dimes to a dollar—with English money having no constant ratio—4 farthings to a penny, 12 pence a shilling, 20 shillings a pound, not to mention 5 and 21 as the ratios of crowns and guineas—and one immediately sees the great advantage of ours over the English system. The child has to learn only one thing, viz. the progression of values; the ratio is constant. He is not in any danger of making the mistake often made by the English child of getting his twelves and twenties mixed. But the real difficulty comes when the English child begins to put his values down on paper, when he begins to add, subtract, multiply and divide English money values. This difficulty lasts him thruout life. How many Americans offhand can give the correct answer in pounds, shillings, and pence to the simple problem of 100 units at 7 1/2d. per unit? (£3 2s. 6d.) Yet every American can answer immediately the problem in dollars and cents of 100 units at 7 1/2¢.

One must be a little on the outside in order to get the right view. The facility with which the Englishman handles his twelves and his twenties does not detract from our wonder that he is able to do it, nor change our judgment that this facility represents an enormous waste of effort. So to the Frenchman or German our apparent ease in handling twos, fours, twelves, sixteens and thirty-twos, in pints, quarts, inches, ounces, and bushels is a subject of wonder, but not of envy.

A mile has 8 furlongs, a furlong 40 rods, a rod 2 3/4 fathoms, a fathom 2 yards, a yard 3 feet, a foot 12 inches and an inch 3 barleycorns. A ton has 20 cwt., a hundredweight has 100 lbs.—unless it be a long ton and then it has 112 lbs.—a pound has 16 ounces—unless it be a troy pound—an ounce has 16 drams, and a dram has 27 11/32 grains. This is all as wonderful as a cubist painting.

Nevertheless, we can be of good cheer. There is worse to come. A Frenchman, a German, or a Brazilian has one quart—he calls it a liter, and it is the same in France, in Germany, or in Brazil. We have two quarts, the wet and the dry. One of them is smaller than the liter, and the other is larger. Our housewives must measure their molasses and vinegar in one and their flour and beans in the other; otherwise the domestic economy goes all awry.

Pints, quarts, gallons, and bushels are an inheritance from Britain, the British wine gallon being the basis of our wet measures and the Winchester bushel of our dry. But the British have discarded both, and adopted a new and larger standard gallon and bushel. So 50 gallons doesn't seem to mean much of anything unless one knows whether it is whiskey or walnuts, American or English.

But the term bushel is used commercially in two senses: as a measure of volume and as a conventional weight. The two are supposed to be interchangeable and are so considered, but they are not. The farmer measures his grain by volume, the buyer, by weight. The volume is standard, the same in every State, but the weight bushel, the bushel of larger commerce, is not. Wheat is 60 pounds everywhere. Rye is 56 pounds in most States, but is 54 in California and 50 in Maine. Barley is 48 pounds in the larger number of States but is 45 in Arizona, 46 in Oregon, 47 in Pennsylvania, Kentucky, Georgia, and Alabama, and 50 in California. Buckwheat is 40 pounds in California, 42 in North Dakota, South Dakota, Oregon, and Washington, 48 in nine states, 40 in seven, 52 in eleven, and 56 in Kentucky. Shelled corn may be anywhere from 50 to 58 pounds, and corn in the ear may vary by law according to the month in which it is weighed. One of the most familiar units of commercial measure is the barrel. Apples, potatoes, vegetables generally, flour, lime, crude oil, cement, and dozens of other commodities are customarily bought and sold by the barrel. For farm produce the measure is ordinarily one of volume; for flour, lime, and so on, it is of weight based on volume. It is important to know what is the size of the base barrel. There is no such thing. A bushel by size is standard, but there is no standard barrel—or rather there are hundreds of standards. The result is that we have all the difficulties of the bushel multiplied scores of times over.

One could pursue this vein thru many channels, and everywhere the same condition is met—confusion and uncertainty, entailing commercial loss and inefficiency. Applied to foreign commerce, the whole mass of incongruities known as the American system of weights and measures is impossible. But we are told that we cannot change it, that it is too firmly fixed. I doubt this.

There are certain manufacturing industries whose tool equipment, upon the inch and foot gauge, cannot be adjusted to the meter gauge; but those are very few. Most tools can be adjusted at but little cost. For the rest, the change here would be easy, as it has proved easy in every country which has adopted the metric system. This statement is sometimes denied. The denial, however, is based upon a confusion of ideas. It has been found somewhat difficult in countries adopting the metric scale to do away with the names of the most used measures, such as yards, quarts, pounds, and so on, or rather of the equivalents of these English words in the language of the country adopting the new system. Pound, libra, livre, pfund, was an almost universal measure. Not always the same, of course, but in most cases very nearly the same. Now in substituting "kilogram" for "pound," it has been found that people were slow to substitute the new word. Take all the various pounds of France, the German states (all different), Austria, Hungary, Scandinavia, Italy, Spain, etc., in general, the kilogram was 2 pounds or a little over. What happened? The people kept the word, but applied it to a half kilogram—500 grams. So we have at present the pfund in Germany, which is not at all the old Hanoverian, Saxon or Bavarian pfund, but is 500 grams. So likewise we have the libra in many Latin-American countries, but it is not the old Spanish libra; it is, as in Germany, the half kilo—500 grams.

It has been found very easy to substitute the thing, altho sometimes difficult to substitute the word. It is the thing that we who advocate the metric system desire, the word is of less importance. It matters but little if, having the meter, we continue to use the word yard. The important thing is that it be of meter length and divided decimally . . .

Scarcely a vestige of the old standard is left in any country that has adopted the metric system. Now and then in Latin American countries one will hear the old words, but almost always with a meaning adapted to the new scale . . .

That we (of the United States of America) must, and furthermore that we shall, come to the metric system is to my mind beyond question. First, because the exigencies of our foreign trade make it impossible for us to do otherwise; and, second, because the present system is too cumbersome, too uncertain, too complicated, and too difficult to learn even for our domestic uses.

International Business Conference Resolution

During a ten-day International Business Conference held in Rye, New York, in November, 1944, the five hundred businessmen attending from fifty-two nations passed the following resolution:

There should be adopted, for use in International Trade, a single system of Weights and Measures, preferably the Metric System and a standardization of containers with reasonable tolerance.

The Armed Forces

The Metric System and the Armed Forces

CAPTAIN GEORGE S. MARTIN, JR., T.C.

EIGHT hundred million dollars! It is interesting to observe that this is a conservative estimate of possible yearly savings in government expenditures alone, should we convert to the metric system of weights and measures. During the normal lifetime of an individual this figure would reach astronomical proportions.

It is hardly conceivable that a government consisting of management experts, scientists, economists, professors, and solid businessmen would knowingly not take advantage of this pecuniary saving. Standing alone, the saving would fully justify the change. There are, however, other reasons for the change more cogent, logical, and fundamental than the saving of dollars and cents.

Billions of American dollars have been loaned to other nations in order to increase and stabilize world trade. Perhaps overshadowing the monetary and physical advantages of the loan is the intangible benefit of establishing good will. While governments jealously strive to attain this concealed factor in many ways and for various reasons, to us as individuals it is by far the most important of all factors. Good will, regardless of its scope, has a marked tendency to decrease criticism, to promote harmonious relations, to preclude and minimize misunderstandings, to serve as a punching bag and absorb blows which might well lead to acts of violence. This latter point is our personal, inherently selfish viewpoint.

Regardless of how infinitesimal a contribution may be in obtaining good will, providing the result is commensurate with expended effort, the beneficial effect is felt indirectly on every hearthstone, in every home.

Speaking a common language has a decided advantage in any transaction, whether it be in diplomacy or sound business practice. It alleviates the possibility of error in the interpretation of the precise meanings of given words or of an entire basic doctrine. On this premise, the use of a basic common system of weights and measures also precludes the possibility of error and of misinterpretation, and, in addition, promotes and establishes easily definable and understandable approaches to a common problem. Surely, archaic weights and measures as perpetuated in the imperial system, which is not fully understood even by its users, are not conducive to harmonious relations or the establishment of good will. The problem of converting imperial weights and measures to metric is time-consuming and unjustifiable.

In the early part of the twentieth century it was recognized that the organizational and procedural pattern of private enterprise and government, with the exception of the human element, could be scientifically determined. Through the years this premise has been carefully applied by a growing profession of industrial and management engineers. We are particularly concerned with a relatively important phase of the scientific evolution of government, namely, the proposed merger of the army and navy. While this is a very controversial subject, the basic theories are logical and its discussion is timely. One advantage alone is sufficient to warrant consolidation—the savings to our fighting men in terms of life itself.

Teamwork, close supervision, careful planning, coordination, and clear, concise delineation of command authority are prerequisites to success in any mutual undertaking. A few of the attendant advantages are: maximum utilization of personnel, integrated intelligence, coordinated logistical problems, elimination of interservice transportation difficulties, specialization, reduction in service jealousies, uniform terminology.

At what better time in our history could we have applied and derived the benefits of the metric system than concurrently with the army and navy merger? Even if our chief legislative body had determined that for various reasons the merger was not practical, the application of the metric system would still be advisable.

The ludicrous and unscientific measures applied to arms of the various services are certainly a deterrent to optimum production from our arsenals and private manufacturers during times of war or peace. Once it is manufactured, the ammunition is restricted to use within predetermined weapons. True, the use to which the weapon is to be put determines such factors as trajectory and muzzle velocity, but these could be controlled by type and quantity of powder and still be interchangeable with weapons of another branch of service.

There are various units of measurement commonly utilized by our armed forces, such as inches and millimeters, gauges, calibers, and so on. It is not conceivable that every soldier understands and is competent instantly to convert foreign measurements to imperial inches. It is fundamental to assume that familiarity with every aspect of one's tools has the advantage of permitting their fullest and most effective use.

The change to the metric system would provide other benefits, such as:

a. Instruction: Approximately two years of a child's time now spent in studying arithmetic would be saved.

b. Comprehension: Depending on the adult, only from one to three hours are required to become familiar with the simple decimal system of computing weights and measures.

c. Savings: Only names and scales are changed, not machinery. Initial costs of conversion would be amortized within a year.

d. Convenience: The difficult conversion problems now met in the exclusive use of the imperial system would not arise in normal business transactions. Any inconvenience occurring as a result of conversion would be more than compensated for within a year.

e. General: No nation having converted to the metric system and having realized the full advantages has then gone back to the imperial. Artificial barriers now created as a result of the imperial system would be removed.

An orientation program is essential. Teachers of mathematics are concerned with simple systems as well as with easy and effective methods of instruction.[1]

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[1] Miscellaneous Publication No. 2, dated September 21, 1922, *The International Metric System of Weights and Measures*, outlining in detail the simplicity of the metric system, is on sale at the Government Printing Office, Washington, D. C., for a nominal fee.

The Metric System Approved[*]

QUARTERMASTER GENERAL, U. S. ARMY

THERE can be no doubt that the metric system is greatly superior to the one now in use. Is the change worth the trouble? I think it is.

More complete international understanding would definitely be promoted by the adoption of common standards.

Major General E. B. Gregory

Athletics

The Metric System in the Olympic Games

AVERY BRUNDAGE

THE Olympic Games and, as a matter of fact, nearly all other amateur sport events of an international character are conducted by the metric system of measurement, which is used officially by most of the great international amateur sport federations. This, of course, is logical enough, since the great majority of the countries of the world use the metric system exclusively. Only the United States and the British Empire continue to use the complicated English system of measurements. This means that most official world's records are tabulated in meters, although it is true that for comparison records are also listed in English units.

Because of its simplified character, because it is used in the great majority of other countries, and because the principal amateur sport events in the world, as was stated above, use it, the metric system was adopted by the Amateur Athletic Union of the United States ten or fifteen years ago for its championships. Shortly after that, the Intercollegiate Association of Amateur Athletes of America, commonly known as the I.C.A.A.A.A., decided to follow suit. (Later it had to return to the English units, as the Amateur Athletic Union has for all but outdoor track events.)

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[*] Reprinted from *This Week* Magazine, April 16, 1944. Copyright, 1944, by the United Newspapers Magazine Corporation. By permission of *This Week* Magazine and of Lieutenant General E. B. Gregory, Retired.

In track and field sports the use of metric units does not alter the character of the events except in one instance, that of the 1,500-meter race, which is somewhat shorter than the mile run. The half mile and the 800 meters, and the quarter mile and the 400 meters are substantially the same distance. In the field events, of course, there is no difference whatsoever. It is true that in distances above the mile the standard events vary considerably, but a 5,000-meter race is just as important as a 3-mile, and the 10,000-meter race has as much merit as a contest at 5 miles. There is enough difference between the 1,500 meters and a mile to change the character of the race somewhat, and an athlete who is good at one distance is not necessarily just as good at the other. This, however, is not very important, although it has resulted in much argument.

Many swimming pools have already been built to Olympic measurements in meters, and considerable progress has been made in this sport toward the adoption of the international metric system. One commonly hears reference to the 1-meter, the 3-meter, and the 10-meter boards among the diving fraternity, and records are quoted almost as often in meters as in yards.

In yachting and quite a few other sports, meters are used commonly by the participants.

The question of simplified procedure is so important in our complex civilization that the government has established a department to standardize processes. This was essential during the war and is equally essential in times of peace. The advantages of the metric system are obvious. However, despite the fact that in the scientific world, meters, liters, and grams are used almost universally, it will be some time before the United States adopts the metric system for general use unless our educational practice is changed or unless the government takes a hand, and this is unlikely.

Despite the fact that the Amateur Athletic Union and the I.C.A.A.A.A. adopted the metric system to conform to international practice, there was considerable public resistance. In fact, the I.C.A.A.A.A. already has returned to the English system. This is largely due to the fact that the participants in, and spectators of, these events had been trained to think in terms of feet, yards, and miles. Until the elementary schools adopt the metric system and our children are taught to think in meters, liters, and grams, it will be difficult to change over and take advantage of this simplified procedure.

We of the sport world can help, but we cannot decide the issue of whether the metric system is to be adopted generally by the United States even in our own field of athletics. Too many people are involved. Not until our educators decide to make the boys and girls in our schoolrooms use the meter stick as readily as the yard stick will public resistance be overcome.

Pan-American games, planned before the war but postponed because of hostilities, are scheduled for 1950. This will give further impetus to the use of the metric system. The amateur sportsmen of the United States are generally favorable to the change; they hope that the simplified system based on the meter will come into use, but they alone cannot overcome the resistance offered by a public which is not educated to that end.

Adoption of the International Standard for Track Athletics in the United States

A. C. GILBERT

Countries Using the International Standard

(All Members of the International Amateur Athletic Federation)

Argentina
Austria
Belgium
Bolivia
Brazil
Bulgaria
Chile
China
Cuba
Czechoslovakia
Denmark
Egypt
Esthonia
Finland
France
Germany
Greece
Haiti
Hungary
Iceland
India
Italy
Japan
Latvia
Lithuania
Luxemburg
Mexico
Netherlands
Norway
Peru
Philippine Islands
Poland
Portugal
Rumania
Spain
Sweden
Switzerland
Turkey
United States?
Uruguay
Yugoslavia

Countries Using the English Standard

(All Members of the International Amateur Athletic Federation)

British Empire:
Australia
Canada
Great Britain
Ireland
New Zealand
South Africa

What is the international standard? The international standard is the metric system of measuring distance for running events:

100 meters instead of 100 yards
200 meters instead of 220 yards
400 meters instead of 440 yards
800 meters instead of 880 yards, and so on

Why do we call it the international standard? It is so named because it is the standard of distance adopted by the International Amateur Athletic Federation. (See lists above for countries which are members of the International Federation.)

What is the English standard? The English standard is the system of measuring distance in terms of 100 yards, 220 yards, 440 yards, 880 yards, 1 mile, and so on. (See the list above of countries using the English standard.)

Why do we call it the English standard? We do so because it is the standard we inherited from the British Empire. It is sometimes called the imperial standard.

FACTS FAVORING THE USE OF THE INTERNATIONAL STANDARD

1. It has been adopted by the International Amateur Athletic Federation; therefore the Olympic Games, even when held in English-speaking countries, must be run under the international standard. The Olympic Games held in London in 1908 used the international standard, not the English standard; the Olympic Games held in the United States in 1932 used the international standard, not the English standard.

2. Its use would make possible recognition of America's leadership in running events. In field events the International Federation records are translated from the English standard to the international standard; that is, from feet and inches to the corresponding metric measurements. In running events records are not so translated. Records made in the English standard are recorded in the archives of the International Federation but receive no recognition; they do not appear on the programs in countries using the international standard. The result is perfectly obvious—lack of recognition of the leadership that we feel we possess in many running events.

3. Its use would give an opportunity to individual American athletes to establish internationally recognized world's records. Prior to the adoption of the international standard by the Amateur Athletic Union of the United States, only once in four years, at the Olympic Games, were American athletes given an opportunity to establish internationally recognized world's records at metric distances, and then sometimes they were deprived of this opportunity by track and weather conditions prevailing at that time. Therefore it was hopeless for American athletes to expect their international records to measure up to the records of foreign athletes who competed regularly at metric distances.

4. Its use in this country would better familiarize, prepare, and train American athletes for competition at distances measured by the international standard. Although the differences between the racing distances measured by the international standard and by the English standard are not great, it would be an advantage to our athletes to be familiar with the metric distances. Familiarity certainly is an advantage in judging pace and in giving pace information per lap so it is not confusing to the runners.

5. Its use would provide greater familiarity with the track performances in other countries, which would better prepare American athletes for international competition. At the present time Americans are not kept familiar with achievements in foreign countries; as a result, they underrate foreign competitors. This accounts for the adverse criticism American athletes have received from the public press many times as a result of their showings at the Olympic Games, criticisms arising wholly from lack of information regarding the achievements of foreign competitors.

6. Its use in this country would increase international publicity and the exchange of information. Because of the fact that the American public is more or less unfamiliar with the world's record times in the international standard, newspapers are now reluctant to publish results of great meets in foreign countries. Furthermore, in the running events it is now difficult to make international comparisons, owing to the use of the two different standards. In general, we need a greater exchange of information; it should and will increase public interest in track athletics.

7. Its use would have the advantage of simplification. No one

can deny the fact that it would be more simple if all standards of measurement throughout the world were exactly alike.

8. Its use would make mathematical calculation easier. The international standard of measurement is metric. The metric system is acknowledged by everyone acquainted with facts to be the simplest system. Its advantages are so apparent as a method of measurement that even in countries where the imperial system is used, many professions have adopted the metric system for convenience, simplicity, and saving of time. In fact, metric measurement is becoming more and more prevalent. Everyone today is buying films in the metric system, rather than in the imperial system. The imperial or English standard is a hodgepodge of yards, feet, inches, miles, rods, hands, furlongs, dozens, grosses, great grosses, stones, pounds, ounces, and so on. These units are an Anglo-Saxon inheritance, and unfortunately we have clung to them merely for the sake of tradition.

Most people are unaware that the metric system was legalized in this country in 1866 and has now been legalized in every country in the world. It is used in chemistry, surveying, and various branches of our government work, in the weights and measurements of our coins, and in writing prescriptions by the modern medical profession. Even in the British Empire, the standard yardstick is now checked back to the meter for absolute accuracy mathematically. Scientifically the metric system is a vast improvement over our old methods of computation. Were it not for sentiment and selfishness, the change would have been made long ago.

Fundamentally and theoretically the metric system is the simplest, most readily learned and understood, and most easily applied of all systems. Many do not realize that even our imperial system because of its inefficiency and confusion, has changed and is constantly changing. Most of the measurements of our forefathers were made in terms of chains and links and rods. Probably as many steel tapes today are divided into tenths of inches or into tenths of feet instead of into inches as are divided into quarters and eighths of inches. All of us who have judged jumping events have sworn at such devices when they have been handed to us to measure the distance of the broad jump, high jump, and so on, and the only reason we have done so is because we are unfamiliar with them, not because they are not accurate. Even England and the United States, both using the imperial system, differ materially on some fundamentals. You seldom, if ever, hear an Englishman weighing 140 pounds do other than say he weighs 10 stone. In point of fact, if you take up any racing program, such as that of the Grand National, you will find the weights put down there in stones and fractions thereof. These are merely some instances showing that even in England and the United States there is no one uniform system of weights and measurements, and that therefore quite frequently in ordinary life, as well as on the athletic field, we have to go through some mental gymnastics to picture in our minds just what such-and-such a weight or performance means.

POINTS POSSIBLY UNFAVORABLE TO THE INTERNATIONAL STANDARD

1. Some objections are sentimental or patriotic. The majority vote taken at the A. A. U. Championships in 1932 did not support these objections. Some of the questions and replies were:

Do you disapprove of track races in the United States being run in metric distances? 2,400 answered, "No"; 1,900 answered, "Yes."

Has your enjoyment of these games been lessened by the fact that the races were run in metric distances? 2,800 answered, "No"; 1,700 answered, "Yes."

2. Change to the international standard is claimed by some to be unfair to old record holders. Those who feel it is unfair to the old record holders should ask themselves this question: Are old record holders remembered by their records or by their achievements? Will Eddie Tolan's records be remembered in the English standard or the international standard? Will not his achievement as the outstanding sprinter in 1932 be remembered whether his records are broken or not? Such athletes as Bernie Wefers, Charlie Paddock, Maxy Long, Johnny Hays, John Paul Jones, Kraenzlein, and others down the line are going to be remembered for their outstanding achievements, even though their records may have long since been broken.

Probably some of you who will read this are record hounds who know and remember records, times, and performances in all the standard events. Frankly, I remember few, but I do remember that Bernie Wefers was the outstanding sprinter of his day and was the most graceful and probably one of the fastest runners of all time. I do not remember whether Meredith's great achievement was measured by the international or English standard, but I have always felt he was one of the fastest runners the world has ever seen. For the life of me I cannot remember how fast Mel Sheppard ran a mile, or what his time was in winning the 1,500 meters at the Olympic Games in London in 1908—but we will remember Mel Sheppard as the outstanding performer of his day.

What really counts and will linger in our memory is not what the record was, or what the system of measurement was, or what the rules were that governed the sport at that time, but the outstanding performers of the time. They will always be remembered and will go down in history as the champions of their day. Probably the writer is more familiar with pole vaulting than with any other event on the program, and what is true of pole vaulting is true of many other events in which improvements, not only in technique, but in the equipment used for the performance, have been made. Would anyone want to go back to the old obsolete equipment—hazardous wooden poles and various kinds of dirt holes? It might in all fairness be said that improved methods make comparisons of records unfair to the old athlete, and yet all of us remember Hugh Baxter, one of the fathers of pole vaulting, whose outstanding performances in his time and under conditions prevailing then will be remembered indefinitely.

I am reminded of the fact that when the great Mike Murphy protested the use of bamboo vaulting poles at the Intercollegiate Games in Philadelphia in 1908, one of the arguments raised in discussing the matter was that it was unfair to old record holders; and yet Jim Sullivan ruled, as he should have, that the bamboo pole was not only perfectly legal, but a step forward. The mere fact that it was adopted as an improvement, a step forward in athletics, has not deprived any of the old record holders of any of their great achievements, or changed the fact that they were outstanding champions of their day. Who, offhand, can remember when the distance from the curb to the edge of the standard track was changed from 18 inches to 12 inches? Who can remember comparing records for races run with spiked shoes and without them? I do not want to convey the idea that I do not believe in records or the recording of them. Comparisons of time are important, but the main point is that they will be of infinitely more value if they can be made among performances throughout the world.

3. It is claimed by some that the change to metric measurements would be confusing to spectators. Ask yourself, "Is the marathon race confusing?" No, it is not; yet the name of the race does not specify any particular distance. The public knows only that the race is long. Unprejudiced minds realize that in a comparatively short time any confusion, if it does exist at first, will be entirely eliminated.

4. Some objections to the metric system are the results of misinformation as to what the international standard means. One such misconception is shown in the mistaken statement that the field events will be announced to the audience in metric units. Another attributes political motives to the exponents of the international standard. A third appears in statements to the effect that all coaches disapprove the change. A fourth consists of the belief that the athletic clubs and universities are opposed to the metric system. Consider, however, the following facts: The A. A. U. Track and Field Committee adopted the international standard unanimously in 1932. The A. A. U. Convention in 1932 adopted it unanimously. Many prominent athletic coaches have approved it. Prominent sportsmen in every state in the Union approved and recommended its adoption. All the outdoor A. A. U. National Championships are run in the international standard distances.

5. Some who object to adopting the international standard measurements ask why the United States should give way to requests of other nations when we could make them look pitiful in any meet. The answer to that is that in the running events at the Olympic Games in Los Angeles in 1932, the United States won only four of the eleven races on the program, exclusive of the relay races and the 50,000 meter walk.

3. *Of Public Interest*

PUBLICITY GIVEN TO THE METRIC SYSTEM THROUGH PRESS, RADIO, AND GROUPS ADVOCATING ADOPTION

Magazines

The Metric System and Latin American Friendship[*]

OTTO E. KRAFT

On October 15, 1942, the Brazilian Government changed its monetary system importantly.

Previously the monetary unit was the milreis (one thousand reis). This small unit, equivalent to roughly five cents U. S. currency, was expressed in figures as: 1$000. The conto or 1,000 milreis, equivalent to about $50 U. S. currency, was written 1:000$000.

Statements of even medium-sized Brazilian houses showed assets running into ten figures (Brazilian currency). For instance, 1,000 contos or one million milreis were written 1,000:000$000, and this was equivalent to but $50,000 U. S. currency. For really large enterprises, in the million-dollar category, the Brazilian figures were astronomical. For example, five million dollars were 100,000:000$000.

The Brazilians, like ourselves and our British cousins, are fond of their traditions and slow to change them; and yet the old system was thrown out of the window and a decimal system of currency was adopted. The "cruzeiro" takes the place of the milreis, and, while the unit itself is a small one, accounting is greatly simplified, as one cruzeiro (Cr.$) is now written "Cr.$1,00," while 1,000 cruzeiros (one conto) are Cr.$1.000,00.

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[*] Reprinted with permission from the January, 1943, issue of *Dun's Review*, published by Dun & Bradstreet, Inc.

So, practically overnight, our great southern friend and ally has discarded its cumbersome system and adopted one better fitted to modern conditions.

We hear a great deal about Hemispheric Solidarity, yet our system of weights and measures is totally at variance with that of the ten South American Republics, the six Central American Republics, and our next-door neighbor and ally to the south, Mexico. In every one of these, as well as in the independent nations of the West Indies and in some of the colonies of foreign powers, the metric system is in use.

Of the large countries in our hemisphere, only Canada and the United States still cling to the archaic and cumbersome system of weights and measures represented by ounces, pounds, tons; gills, pints, quarts, and gallons; inches, feet, yards, rods, and miles. Aside from this we have troy weight and avoirdupois, the short ton and the long ton, and many other units which mean absolutely nothing to the other countries of this hemisphere and often are not thoroughly known to our own people.

We have all heard the riddle, "What weighs more, a pound of gold or a pound of feathers?" Sounds silly, doesn't it? A pound of gold, for which troy measure is used, is equivalent to 5,760 grains; while a pound of feathers, for which avoirdupois measure is used, is equivalent to 7,000 grains. So a pound of feathers weighs 1,240 grains more than a pound of gold!

Unless you are a farmer or a surveyor, the chances are you do not know offhand how many square feet or square yards or square rods there are in an acre, or how many acres in a square mile.

Is not this the time to start thinking of throwing our antiquated system into the discard and of adopting the metric system?

IMPLEMENTING A SLOGAN

That would be one way of proving to our Latin-American neighbors, friends, and many actual allies in the war, that we really mean "solidarity" with them, instead of regarding the word merely as a slogan.

Think of the advantages to the Brazilian exporter of essential raw materials if he can quote prices in kilograms without figuring out the equivalent in pounds; to the Colombian importer who needs so many meters of goods and does not have to convert them into yards; to the Mexican manufacturer who has so many square meters of floor space for machinery he requires and does not have to convert them into square feet.

After the war we shall, sooner or later, face European competition again. I have repeatedly heard the statement made in Latin America that it is easier to handle European than United States merchandise because the Germans, the French, the Spaniards, the Italians use the metric system and we do not. If we can eliminate that complaint, it will undoubtedly swing some business to the United States and tie us more closely.

Shortly after the fire on the *Normandie* many stories were heard about why it was possible for that magnificent liner, reputed to have had the finest fire-fighting equipment available, to have been so severely damaged by fire in such a short time. One was that the hose had deteriorated and that the hydrants had the French metric threading, while the hose couplings available in the United States had American threads; and the delay in changing the hydrants made it impossible to use the hose when it was so badly needed. No one can be held to blame for this, if it is true; but if the threading had been uniform, the *Normandie* might already have ferried thousands of our boys across the seas to points where they are so vitally needed.

Many of our large factories are now working solely on war orders. When the war is over they will have to start anew on commercial business. Already methods of packaging and types of containers have been changed. Changes of dimensions and of weights are the next logical step.

It may be admitted freely that changing our whole system of weights and measures, especially land measures, would present a great many difficult problems; but they are not insurmountable. We have seen some of these changes in our own lifetime. In Mexico, for instance, within the past decade the time-recording system was officially changed. From the twelve-hour clock a change was made to the twenty-four hour clock. There was a lot of grumbling at the outset; the measure was "radical" and "new-fangled."

However, all official time is now on the twenty-four hour schedule, and all railroads use it. It was not necessary to change the dials of the clock; numbers from 13 to 24 were placed under or over those from 1 to 12. All doubt as to whether your train leaves at 6:32 A.M. or 6:32 P.M. is done away with. The timetable says it leaves at 18:32, so you know you have the whole day before you roll out of the Buenavista Station in the early evening.

Incidentally, our army and navy have been using the twenty-four hour schedule. If you are in a fox-hole on Guadalcanal and are notified by field telephone that the zero hour is 4:02, you do not have to ask "A.M. or P.M.?"

TIME FOR CHANGE

That is a change brought about by the war and we may see it in more general use before the war is over.

The war has already caused radical changes in our whole mode of life. You are driving more slowly and driving less. You cannot say "fill 'er up" when you go around to get gas. You cannot get the sugar you used to, nor the meat, nor the coffee, nor the golf balls, nor the tires. A year ago, we would have considered those changes "radical." Yet we have taken them in our stride and we shall take many more.

Our whole system of living is changing and it will surely change even more.

Is this not the time to adopt the metric system, or at least those weights and measures used in our dealings with foreign countries?

Let's Go Metric*

J. D. RATCLIFF

ASK your neighbor to define a troy ounce, a gill, a furlong, or a drachma. His failure to answer correctly is no reflection on him. It is a reflection on the absurdity of our system of weights and measures.

It is a perfectly safe bet that *no one* in the United States can accurately define all the units in the system: the grains, scruples, pennyweights, the three kinds of tons, the 56 kinds of bushels. The Bureau of Standards uses over 500 fine-type pages to do the job.

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* Reprinted from *This Week* Magazine, April 16, 1944, with permission of the author and of the publisher. Copyright, 1944, by the United Newspapers Magazine Corporation.

The ancient Chinese had an "uphill" mile and a "downhill" mile. They logically contended that it was harder to walk up a hill than down; and that the uphill mile should be shorter. Smile if you will. But look at our system. Ask the old question: which is heavier, a pound of gold or a pound of feathers?

Silly, you may say. But wait a moment. Feathers are weighed by avoirdupois, gold by troy. The avoirdupois pound is 7,000 grains, the troy, 5,760 grains. Therefore, unless you define terms carefully, a pound of feathers weighs more than a pound of gold.

There is one way out of this horse-and-buggy system of weights and measures: join the world parade and adopt the metric system. It is the only scientific system. It has been adopted by every country in the world except Great Britain and ourselves. Every country south of the Rio Grande uses it. So does all of Europe and the Orient—including "backward" China. After once trying out metric, no country has ever gone back to its old system. *Metric is the decimal system we use in our money applied to weights and measures. Everything is in units of 10; hence there is no need for fractions.*

This is, perhaps, the critical time in our national history to make such a switch. There will be big jobs to be done in the postwar world. The change to metric is one of the smaller jobs which should get top priority. Millions of soldiers will be returning from overseas, where they have become accustomed to kilometers, meters, liters. Thousands of factories will have to be retooled for peace—they may as well be retooled in metric.

WE'RE BORN ON METRIC

Of their own volition, a great many industries have already switched over. Almost the entire chemical industry is based on metric measurements. Because of the great saving of time, and of wear and tear on brains, many machinery companies and manufacturers use metric exclusively. We buy vitamins by metric weight, tune our radios to meter waves and follow sports events where metric measurements are used. For the sake of simplicity, safety, and convenience, physicians write prescriptions in metric. We even enter the world on the metric system—nearly all hospitals weigh newborn infants in terms of grams.

Our decimal monetary system is the essence of simplicity.

We recognize the contrasting awkwardness of the British monetary system—yet we cling to a system of weights and measures which is even more archaic. To appreciate the beautiful simplicity of metric measurements, consult your child's arithmetic book.

Look at this sample problem: find the number of cubic yards in a room which measures 7 yards 14 inches, by 12 yards 23 inches, by 4 yards 5 inches.

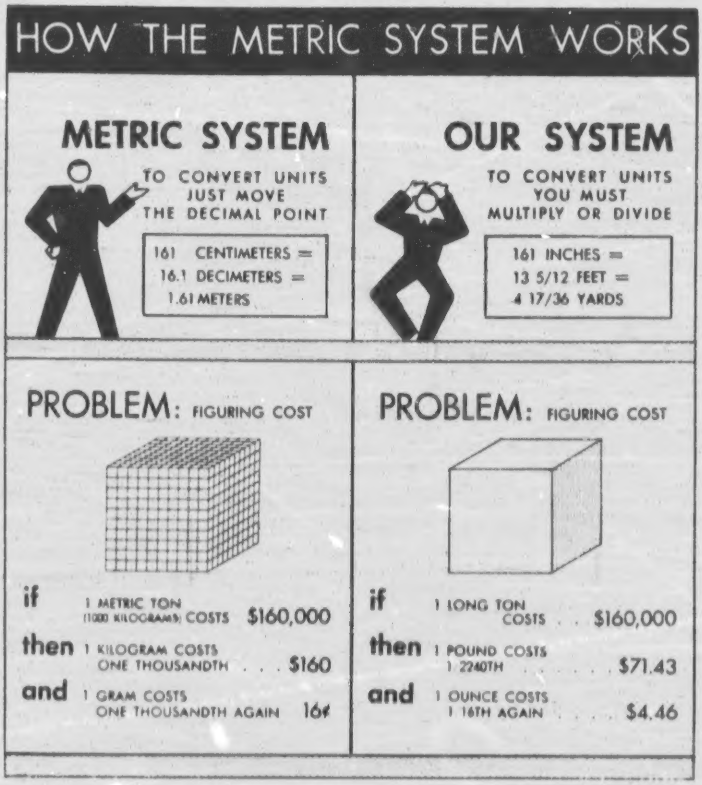
Contrast this with the same problem in a French, Chilean, or Russian textbook. Find the number of cubic meters in a room which measures 11.42 meters by 5.25 meters by 3.9 meters. A clock would be needed to measure the amount of time consumed with the first problem; a stop watch with the second.

Take another problem: Convert 11 pints, 2 gills into gallons. That takes time. But to convert 6,479 cubic centimeters into liters one needs only to place a decimal point—6.479 liters. This speed and accuracy endear metric to all scientific men and engineers. Without exception, they are for the changeover—and the sooner the better.

Educators estimate that the metric system, by eliminating fractions, would save at least a year of time spent by children learning arithmetic. For industry, the savings in dollars would be even more dramatic. One factory which switched to metric estimated in one year it saved 10 times the cost of new measuring devices. A railroad estimates metric would save it $50,000 a year in paper work.

Adoption of metric would put everything on one standard, and eliminate confusion that exists in many places—the Army, for example. The Army uses four measures of gun size: inches for coast artillery; millimeters for field guns, calibers for rifles and machine guns; gauges for shotguns.

To a large extent, we cling to our present system purely because of inertia. Examine some of its absurdities. The foot, for


HOW THE METRIC SYSTEM WORKS
METRIC SYSTEM
TO CONVERT UNITS JUST MOVE THE DECIMAL POINT
161 CENTIMETERS =
16.1 DECIMETERS =
1.61 METERS
OUR SYSTEM
TO CONVERT UNITS YOU MUST MULTIPLY OR DIVIDE
161 INCHES =
13 5/12 FEET =
4 17/36 YARDS
PROBLEM: FIGURING COST
if 1 METRIC TON (1000 KILOGRAMS) COSTS $160,000
then 1 KILOGRAM COSTS ONE THOUSANDTH . . . $160
and 1 GRAM COSTS ONE THOUSANDTH AGAIN 16¢
PROBLEM: FIGURING COST
if 1 LONG TON COSTS . . $160,000
then 1 POUND COSTS 1 2240TH $71.43
and 1 OUNCE COSTS 1 16TH AGAIN $4.46

example, was originally anyone's foot—without regard to shoe size. Edward II decreed that three barleycorns made an inch; and Henry I specified the yard as the distance from the tip of the royal nose to the tip of the royal right thumb. The rod was the sum of 16 left feet placed heel to toe, the left feet being supplied by the first 16 men who emerged from church on Sunday. Thus, our hopeless patchwork of measurements sprang up.

WOULD END CONFUSION

The metric system was devised to end all this confusion—by arriving at a minimum number of units, and placing all these units on the decimal system. During the French Revolution the National Assembly appointed a commission of scientists to do the job. The French scientists arbitrarily decided that the basic unit of measurement should be the meter, which was one ten-millionth of the distance from the Equator to the North Pole. The meter turned out to be the rough equivalent of our yard—39.37 inches. Like our dollar, the meter was divided into 100 equal parts—centimeters. It was multiplied by 1,000 to make the kilometer—which is about three-fifths of our mile. Thus, instead of saying that it is so many miles, so many feet, and so many inches from one point to another, the metric system expresses the distance in decimals—4.56 kilometers. The metric measure of land area is the hectare—10,000 square meters, roughly two and a half acres.

The weight of one cubic centimeter of pure water became the basic measure of weight—one gram. One thousand grams composed a kilogram—2.2 pounds. One thousand cubic centimeters became the liter—slightly more than our quart. Thus, metric has but three basic units: liter, gram, meter. Everything else is either a subdivision or a multiple of these units. They are convertible, one to the other. Thus, 1,000 cubic centimeters make a liter; a liter of pure water weighs a kilogram.

One prominent educator declares that he can teach metric to any reasonably intelligent person in less than an hour.

ENGINEERS ARE CONVINCED

More and more our engineers are going to foreign countries to build railroads, power plants, bridges. Often, when they accept these jobs, they fear they will have difficulty in dealing with new units of measurement. To a man, they report no difficulty whatsoever. Their calculations are simplified immeasurably, and they come home ardent metric fans.

Adoption of the metric system would give this country a tremendous advantage in world trade. Our salesmen would go into foreign countries speaking a familiar language of weights and measures.

Japan and Germany, both on metric, had a trade advantage in

South America in prewar days and walked away with a large share of the market. If we discard our clumsy system and get in step with the rest of the world, this advantage will be ours.

What about Great Britain? It has long been obvious that if we were to switch, Britain would have to—it couldn't remain isolated in the world. Similarly, if Britain changed to metric, we would have to follow. So it's a question as to who will make the first move.

Exactly how difficult would the changeover be? Since there are but three basic units in the metric system, the average person should be able to adjust himself in a few days' time. We would have to learn to think of auto speeds in terms of kilometers per hour, instead of 60 miles per hour. But the general similarity of other units would ease the task. The liter is close to our quart. Half a kilogram is near to our pound.

Why, then, haven't we changed—long ago? Congress legalized the metric system in 1866. But this act only made its use permissible. We long ago decided that metric should be used in Hawaii, the Philippines, and Puerto Rico—but have resisted efforts to avail ourselves of its advantages at home. Several times Congress has considered bills which would make the use of metric compulsory. The last time was in 1926.

A small but vocal minority opposed the bill. It gave voice to a widespread misconception—that all machinery would have to be scrapped. This, of course, isn't true. Only the names of things are changed.

Road signs, railway mile posts, scales, rulers, calipers would have to be changed. The bill of 1926 proposed that a 10-year period be allowed for such changes. Other countries have done this without suffering hardship. In this time large amounts of old equipment would have to be scrapped—and could be replaced with the new metric.

NOW'S THE TIME

The urge to change is becoming more and more widespread. As we have noted, a number of manufacturing plants have already gone over to metric. Henry Ford and other industrialists are ardent advocates. Nearly all scientific and engineering societies are heartily in favor of it, and so are physicians. Pharmaceutical houses, jewelers, optical-goods manufacturers have changed already.

A survey of educators, manufacturers, engineers, and physicians several years ago showed 80 per cent for the change to metric. Manufacturers—where most opposition is supposed to lie—favored it two to one!

Even the most voluble critics agree that we will eventually switch to metric. It isn't likely that history will ever present us with a chance as favorable as the present.

"Turning the Table" of Decimal Equivalents[*]

J. T. JOHNSON

AN INTERESTING but entirely overlooked situation is presented by the table of decimal equivalents which is so familiar to everyone in the metal manufacturing field. The table, so often presented as a chart and frequently seen about the shop and drafting room, contains sixty-four items running from 1/64 to 64/64 and from one to six places of decimals [see page 142].

It will be noticed that more than half of the items contain six-place decimals.

This table does a great injustice to the decimal system. Most of the users are grossly misled as to the real nature of the system. For instance, the impression prevails that it takes a five-place decimal to express a fraction as large as 1/32, and a decimal of six places—0.015625—to express a fraction as large as 1/64. Thus the tendency is for the user to think that the decimal is a very clumsy and unwieldy fraction, whereas the opposite is true.

Not until the advent of the automobile in 1900 did the decimal begin to come into its own. This was due to its simplicity and advantages for close fits. The finer parts of the automobile required measurements closer than the sixty-fourths which in many shops had been the closest unit of measurement up to that time.

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[*] Reprinted from *Modern Machine Shop*, June, 1945, by permission of the publishers.

I. Table of Decimal Equivalents

1/64 = .015625
1/32 = .03125
3/64 = .046875
1/16 = .0625
5/64 = .078125
3/32 = .09375
7/64 = .109375
1/8 = .1250
9/64 = .140625
5/32 = .15625
11/64 = .171875
3/16 = .1875
13/64 = .203125
7/32 = .21875
15/64 = .234375
1/4 = .2500
17/64 = .265625
9/32 = .28125
19/64 = .296875
5/16 = .3125
21/64 = .328125
11/32 = .34375
23/64 = .359375
3/8 = .3750
25/64 = .390625
13/32 = .40625
27/64 = .421875
7/16 = .4375
29/64 = .453125
15/32 = .46875
31/64 = .484375
1/2 = .5000
33/64 = .515625
17/32 = .53125
35/64 = .546875
9/16 = .5625
37/64 = .578125
19/32 = .59375
39/64 = .609375
5/8 = .6250
41/64 = .640625
21/32 = .65625
43/64 = .671875
11/16 = .6875
45/64 = .703125
23/32 = .71875
47/64 = .734375
3/4 = .7500
49/64 = .765625
25/32 = .78125
51/64 = .796875
13/16 = .8125
53/64 = .828125
27/32 = .84375
55/64 = .859375
7/8 = .8750
57/64 = .890625
29/32 = .90625
59/64 = .921875
15/16 = .9375
61/64 = .953125
31/32 = .96875
63/64 = .984375
1 = 1.0000

To make the common fraction small enough for close work by successive halving, as the table does, it would be necessary to continue as follows: 1/2, 1/4, 1/8, 1/16, 1/32, 1/64, 1/128, 1/256, 1/512, 1/1,024, 1/2,048, 1/4,096, 1/8,192. And still we haven't arrived at a fraction as small as the ten-thousandths of an inch which is in common use in automobile design and other fine work. The decimal, on the other hand, arrives at a fraction as small as 1/10,000 in four steps, as follows: 0.1, 0.01, 0.001, 0.0001.

The fraction 1/8,192 converted to a decimal equivalent would be written thus: 0.0001220703125—a monster of thirteen decimal places. To the person not familiar with the basis of the decimal system it might appear that in order to use a decimal as small as 1/8,192 inch one would have to use this thirteen-place decimal. Here is where the old table of decimal equivalents is misleading, because it may be difficult to see that a fraction smaller than 1/8,192 can be expressed by the simple decimal 0.0001 and that 0.0001 is smaller than 0.0001220703125.

II. Table of Common Fraction Equivalents

.1 = 1/10	.01 = 1/100	.001 = 1/1,000	.0001 = 1/10,000
.2 = 1/5	.02 = 2/100	.002 = 2/1,000	.0002 = 2/10,000
.3 = 3/10	etc.	etc.	etc.
.4 = 2/5	...	...	...
.5 = 1/2	...	...	...
.6 = 3/5	...	...	...
.7 = 7/10	...	...	...
.8 = 4/5	...	...	...
.9 = 9/10	.99 = 99/100	.999 = 999/1,000	.9999 = 9,999/10,000

Let us turn the table and make some comparisons.

Where the first fraction, 1/10, shown in Table II above, requires four characters (three figures and a line), its decimal equivalent requires but two characters (one figure and one point). Likewise it is seen that the last decimal, 0.9999, requiring five characters, uses ten characters in its common fraction equivalent, 9,999/10,000.

It is not the purpose of the writer to compare the advantages in addition and subtraction and other processes possessed by the two systems; this would require another article. The writer merely wishes to correct the erroneous notion for which the table of decimal equivalents may be responsible; namely, that a six-place decimal is necessary to express a fraction as large as 1/64.

In a technological and streamlined age, with simplification a necessary objective, is it not time to turn the tables and let the decimal come fully into its own?

In Favor of the Metric System[*]

Dear Sir: In a letter published in the July issue, Leonard C. Jordan offers objection to a change to the metric system of measurement. However, he does not advance a single logical argument against the suggested change.

In his first paragraph, Mr. Jordan makes the amazing deduction that advocates of the metric system recommend that its use be made compulsory. To my knowledge, no specific plan has been outlined for achieving universal adoption of the system. A starting point might be an agreement among engineering societies to use it exclusively in publications under their jurisdiction. Government agencies might be induced to do likewise. Its general adoption by industry would be more difficult. At any rate, compulsion does not appear to me to even enter into the question.

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[*] Reprinted from the October, 1945, issue of *Civil Engineering* by permission of the publishers.

Mr. Jordan follows the above deduction with the statement that the established system (English system) is "now preferred by those who use dimensions and do the mathematical work connected with them." I wonder where Mr. Jordan has been living during the past ten years. During that period, at least, I have heard countless engineers and other professionals lament the clumsiness of the English system, and Mr. Jordan is the first one I have run across who prefers it. I don't doubt that there are others who prefer the retention of the English system, but if they are in a majority or even a sizable minority, they have remained strangely inarticulate.

In his second paragraph, Mr. Jordan indicates that he does have an inkling of the principal incentive for universal adoption of the metric system—the advantages, from the standpoint of international trade, of a common system of measurement. He states however, that "the United States and Great Britain have done more with feet and inches than the rest of the world has done with meters," and for some mysterious reason proposes this debatable claim as evidence that the rest of the world could change to the English system more easily than we could change to the metric system. His boast about the progress of the United States and Great Britain is patriotic, but does he expect us to believe that that progress is attributable to the use of feet and inches? The metric system is already in considerable use in both the United States and England, and is more familiar to us than is the English system to most others. That the metric system is simpler is too evident for discussion.

True, the English system could be converted into a decimal system to a greater extent than the present tenth-of-a-foot usage in surveying, but would such an abortion be more practical than the adoption of a ready-made system already in use in most parts of the civilized world? Mr. Jordan seems concerned chiefly with linear dimensions. Does he contemplate setting up weight, area, and volume systems, including tenths of pounds, tenths of gallons, tenths of cubic feet, and others?

He informs us that the metric system is "no cure for all ills" and "no guarantee against mistakes." I have never read any claims, by proponents of the system, that it is, and I cannot conceive of any system that would offer such a Utopia. Mr. Jordan suggests that the metric system involves increased opportunity for errors in locating decimal points. Perhaps he considers fractions not susceptible to error. The fact that the metric system eliminates the use of fractions is a leading advantage of the system, and good engineers do not get gray determining the location of their decimal points.

In his last paragraph Mr. Jordan states that the period ahead will be too "trying and uncertain" to permit the disturbance of present standards. The future is always uncertain and is always trying to defeatists, and a meritorious change should not have to await the pleasure of "those who do the work that would be most seriously disrupted by the change." As has already been pointed out by many, the retooling necessary in the reconversion of war plants to civilian production offers an unusual opportunity for change-over to the metric system with minimum cost and confusion.

Maurice N. Amster
Associate Member, American Society of Civil Engineers

Chattanooga, Tennessee

Metric System Widely Used*

EBASCO SERVICES, INC.

To the Editor: I was pleased to see, in the October 1945 issue, the three letters on the metric system. This correspondence evidences the interest of engineers in the subject. As is well said in one of the letters, discussion of this important matter should be calm, avoiding prejudice and bitterness.

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* Reprinted from the February, 1946, issue of *Civil Engineering* by permission of the publishers.

Our company has for many years used metric units in drawing plans for construction in Latin America and other countries that have adopted the metric system. Engineers and draftsmen, who had heretofore used English measures only, soon learned to use the metric system efficiently. We are therefore interested in the progressive use of metric measures in this country; inefficiency results from the continual necessity of converting from one system to the other. Personally, I believe it will be desirable to work out over a term of years, a method of adopting the metric system in this country and gradually superseding the English.

I was glad to note in L. M. Winsor's article, "Flood Control and Diversion Works in Persia," also in the October number, that he made use of metric measures, trusting to the intelligence of readers of *Civil Engineering* to understand the units used.

Whether or not our country will eventually adopt the metric system of weights and measures, it would appear intelligent for our engineers and writers to recognize that practically the entire world, except the United States and Great Britain, utilizes the metric system. *Civil Engineering* doubtless has readers throughout the non-English-speaking world, and it would seem wise to cater to them in some degree, rather than to use English units exclusively in articles.

Among the letters in the October number is one from Paul Van Buskirk, suggesting the use of "uncial parts" in expressing measurements of length. I have also read recently of a number of systems incorporating decimal subdivisions of a basic unit; one of these, the so-called "Macroblox Decimal System," adopts a basic unit equivalent to 40 in.

It appears that advocates of adherence to English measures go through strange contortions in the attempt to make these measures convenient for everyday use, and to avoid the awkward ratios of conversion between different units and the use of vulgar fractions. The way to obtain full advantage of decimal measures is by gradual adoption of the metric system, with its relatively simple units and relations between units, and with its uniformity with the practice of over fifty countries throughout the world.

Louis Elliott
Consulting Mechanical Engineer

New York

Let's Go Metric*

How much longer will the English-speaking peoples, who pride themselves on their contributions to human progress, lag behind the rest of the world by accepting an antiquated, time-wasting and cumbersome system of weights and measures?

English weights and measures have come down from primitive times by a process of unregulated development, resulting in troublesome inconsistency as between various units and groups of units. In the English system there is no one common relation between the units of weight, size or capacity. This lack of relationship adds much labor to numberless calculations, particularly as quantities are frequently expressed in terms of two or more units; such as feet and inches, or pounds and ounces. Only during the present century did the decimal come into its own. The Table of Decimal Equivalents, though essential in many engineering calculations, has been a pain in the neck to many a busy man.

The metric system, first adopted in France in 1799, has since been adopted by all nations except the United States and the British Empire. It has abundantly proved its superiority and time-saving qualities in all fields, including those of industry and engineering.

The Metric Association has inaugurated an aggressive campaign to place the United States on a metric basis. Dr. J. T. Johnson, the association's president, states that a flood of inquiries and comments on the metric system has been coming from business, engineering, and industrial groups which in the past have been more or less indifferent to a switch to metric weights and measures because they feared the cost of such a change.

In a changeover from English units to metric, some confusion would doubtless result. There would be a period during which both systems would be used; until the metric in general practice supersedes the English. However, the period of disadvantage would be only temporary—a matter of a few years—while the benefits of the metric system would be permanent. Not to be overlooked among these is simplification of many matters in connection with commerce with nations where the metric system prevails.

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* Reprinted from *Industrial Improvement,* July, 1946, by permission.

If a change to metric practice is ever to take place in the United States and in British lands, this immediate postwar period appears to be most favorable. A large number of Americans, in industry as well as the armed forces, have perforce become familiar with metric measures.

We quite agree that "now is the time."

Proposal for Adoption of the Metric System*

OHIO VALLEY HARDWARE AND ROOFING COMPANY

YOUR editorial in the July 1946 issue of *Industrial Improvement,* entitled "Let's Go Metric" is certainly deserving of praise. It seems to the writer that it is high time that we discard our antiquated standards of weights of measures, and the writer would also like to see the adoption of the centigrade thermometer and the twenty-four hour clock, to further coincide with the rest of the world.

As the metric system has been legal in the United States for many years we wonder if the problem is not largely one of developing a program for the abandonment of the old English standard. For example, a program such as the following might tend to reduce the shock of such a turnover, and result in much less objection on the part of those who fear the cost of such a change.

Step I. At a given date, announced months in advance to reduce confusion, the old English standards become illegal on pharmaceutical, scientific and allied items. This step would involve but little confusion.

Step II. At a second given date the old English standards can become illegal on all items of groceries, food stuffs and allied lines of consumer goods.

Step III. At a third given date the old English standards could become illegal on items of basic raw materials. This would include such items as steel, lumber, coal, oil and similar lines.

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* Letter to S. J. Borchers, Editor of *Industrial Improvement*. Quoted by permission of Roger K. Becker.

Step IV. Most difficult step will be the changing over of real estate transactions to the metric system. This can come last. This step will probably require some time, but if after a certain deadline date all deeds and documents of record are required to use metric descriptions, confusion should be reduced to a minimum.

We quite agree that now is the time to get started.

Roger K. Becker

Evansville, Indiana
July 31, 1946

Let's Eliminate Fractions*

C. J. ARNOLD

We are now using two separate systems of measurements for weight, length, volume, and temperature, when one system is all that is necessary for carrying on any or all of our activities. Why should we be burdened with working with, and learning and teaching, two systems instead of only one?

This situation has existed for a long time and will continue to exist so long as those who occupy positions of leadership in the field of education fail to act.

The explanation for this lack of action is in all probability due to the fact that we have grown up with it and, therefore, have accepted it without questioning. We inherited one system, the English system, and the other, the metric system, has come in by slow degrees. We will have to admit that someone with the proper vision along the way could have prevented the present situation. Thomas Jefferson did it for us with our money system. Why couldn't there have been someone to give us a simple and modern system of measurements? Think of all the difficulties it would have saved us today. But there wasn't anyone, and so it is up to us today to correct the situation.

We find ourselves using two systems of measurements when one is all anybody needs. We should get rid of one or the other.

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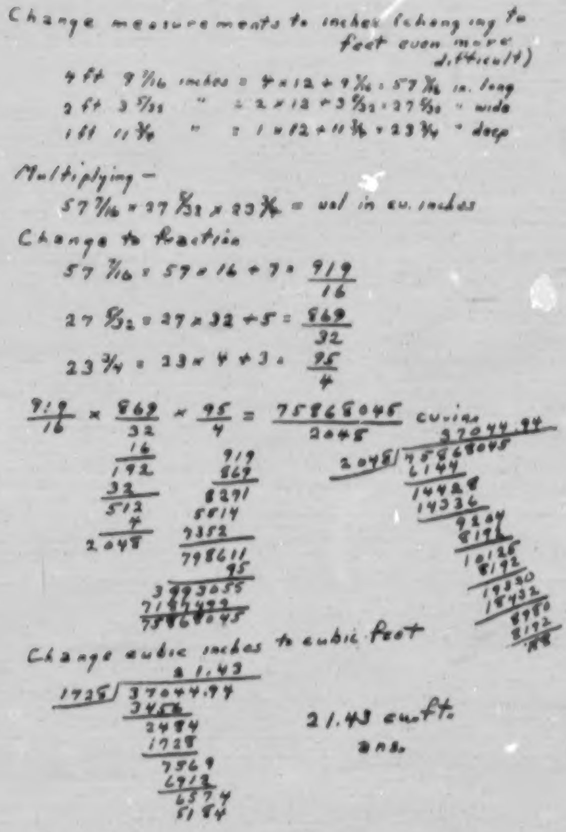
* Reprinted from the *Minnesota Journal of Education*, March, 1946, by permission of the publishers.



Change measurements to inches (changing to feet even more difficult)

4 ft 9 7/16 inches = 4 × 12 + 9 7/16 = 57 7/16 in. long
2 ft 3 5/32 " = 2 × 12 + 3 5/32 = 27 5/32 " wide
1 ft 11 3/4 " = 1 × 12 + 11 3/4 = 23 3/4 " deep

Multiplying —
57 7/16 × 27 5/32 × 23 3/4 = vol in cu. inches

Change to fraction
57 7/16 = 57 × 16 + 7 = $\frac{919}{16}$
27 5/32 = 27 × 32 + 5 = $\frac{869}{32}$
23 3/4 = 23 × 4 + 3 = $\frac{95}{4}$

$\frac{919}{16} \times \frac{869}{32} \times \frac{95}{4} = \frac{75868045}{2048}$ cu in

16
192
32
512
4
2048

919
869
8271
5514
7352
798611
95
3993055
7187499
75868045

37044.94
2048 | 75868045
6144
14428
14336
9204
8192
10125
8192
19330
18432
8980
8192
788

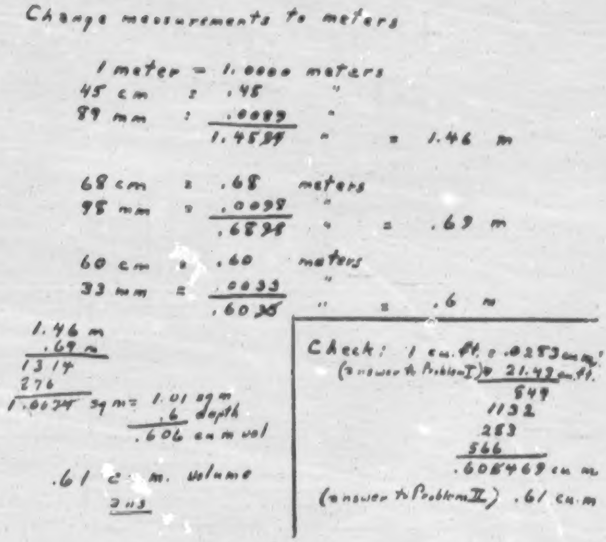
Change cubic inches to cubic feet

21.43
1728 | 37044.94
3456
2484
1728
7569
6912
6574
5184

21.43 cu. ft.
ans.

Problem I. English Measurements. Find the volume in cubic feet of a tank 4 feet 9 7/16 inches long, 2 feet 3 5/32 inches wide, and 1 foot 11 3/4 inches deep.

By simple mathematics we can figure that it will take twice as long to learn (or to teach) two systems of measurements as it does to learn one, assuming of course that they are both equally difficult. But that is not all, for in addition to learning two systems we must learn equivalents in order to be able to change the units of each system into the units of the other. This means that we have made this part of schooling at least four times as difficult as it need be, to say nothing of the added confusion to the learner.



Change measurements to meters

1 meter = 1.0000 meters
45 cm = .45 "
89 mm = .0089 "
1.4589 " = 1.46 m

68 cm = .68 meters
98 mm = .0098 "
.6898 " = .69 m

60 cm = .60 meters
33 mm = .0033 "
.6033 " = .6 m

1.46 m
.69 m
1314
276
1.0074 sq m = 1.01 sq m
.6 depth
.606 cu m vol

.61 c. m. volume
3 hs

Check: 1 cu. ft. = .0283 cu m
(answer to Problem I) × 21.49 cu. ft.
849
1132
283
566
.608469 cu m
(answer to Problem II) .61 cu. m

Problem II. Metric Measurements. Find the volume in cubic meters of a tank 1 meter 45 centimeters 89 millimeters long, 68 centimeters 98 millimeters wide, and 60 centimeters 33 millimeters deep. The author shows how much more time is involved in using English measurements than in using the metric system. Note the check section above, proving the equivalency in the answers. In actual practice, metric measurements would usually be taken in only one unit: Find the volume in cubic meters of a tank 145.89 centimeters long, 68.98 centimeters wide, and 60.33 centimeters deep. In this case, the solution would be still shorter and would involve only the computation shown directly to the left of the check above.

Efficiency in Education and in Living demands that we get rid of one system or the other.

It has been estimated that approximately twenty per cent of the time of the average student is wasted because of this situation. How can such needless waste of the student's time and energy be justified in this so-called progressive day and age? How can we justify the wasting of the teacher's time in such needless duplication?

If there are any doubts in anyone's mind, let him consider the case of High School Physics. When one goes through the textbooks, it will be discovered that approximately forty per cent of the work of learning this subject, as now taught, would be eliminated by using only one system of measurements. Check over the problems the student is asked to work, and the percentage will be found to be even higher. In every unit the student studies he is confronted with the same dual system—he has to learn the acceleration of gravity in feet per second as well as in centimeters per second—he has to deal with density in pounds per cubic foot as well as in grams per cubic centimeter—he must know how to change Fahrenheit temperature readings to centigrade readings and vice versa—he must use BTU's as well as calories, watts as well as Horse Power, and so on ad infinitum. All this duplication of work would be eliminated, and the time saved could be used to much better advantage in studying the many new developments in this field. What is true in high school physics is true in varying degree for all the sciences, and for any subject that has anything to do with measurement.

The first step in the solution of this problem seems self-evident. We must decide to keep one of the systems of measurements now in use and discard the other. Our solution is not the adoption of the metric system, as some have said. We have already done this. Congress legalized the metric system as far back as 1866. In fact, it is our basic standard, and interestingly enough most of the English units are defined in terms of the metric standards. We must get rid of one of these systems, and after we have weighed the advantages and disadvantages of each system there seems to be but one correct course of action—the elimination of the obsolete and complicated English system.

Moreover, the elimination of the English system would simplify our teaching of mathematics as much, if not more, than it would the teaching of science. This is because the English system is a "fractions" system while the metric system is a decimal system. When we discard the English system we will for all practical purposes have eliminated "fractions," as such, from education. True, we will still use fractions to express relationships in formulae and to indicate division problems, but otherwise fractions will pretty much disappear.

Even those who follow market quotations will find the "tenth" in decimal form more adaptable to their needs than the fractions now used. And the machinist will find it easier to use the decimal system than his present measurements in 1/16, 1/32, etc., of an inch. Even now the machinist is forced to turn to the metric method when he wishes to make fine measurements.

The abolition of the English system of measurements of weight, length, volume, and temperature can be justified in many other ways, but as far as the educator is concerned the resulting simplification of education which it would bring about is ample justification. Coming generations of children should not be condemned to waste precious hours of time and energy working with an obsolete and dual system of measurements.

Shall We Cling to the Inch?*

FRED H. COLVIN

After a lifetime on the other side, Mr. Colvin is changing his mind. He presents some of the arguments for the metric system and some of the problems

With all the commendable work that has been done in simplifying as well as standardizing machine parts, we may be approaching the time when we must seriously consider a very controversial phase of the subject—the basis of our measuring units. Only men past middle age probably recall the bitter battles attending earlier attempts to have the metric system made the basic measurement and to compel its use in all government supplies. Frederick A. Halsey, backed by the entire machine-tool industry, fought, both in the columns of *American Machinist* and in Congress, for retention of the English standards. Fred J. Miller, Dr. Stratton of the Bureau of Standards, and others argued the advantages of the metric system, but were decisively defeated. A second attempt, in the early part of the century, also failed.

But in spite of all our logic as to the advantages of the English inch as the basis of measurement in machine building (and it is a most convenient unit when subdivided into fine decimal parts), the metric units have crept into our shops as well as into many of our laboratories. For this kind of work, the inter-related units of the metric system have many advantages, even though it is a foreign language to many in strictly mechanical fields.

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* Reprinted from the March 13, 1947, issue of *American Machinist* by permission of the publishers and of Fred H. Colvin.

Great Britain, the home of the English system of measurement, long ago began to use millimeter sizes for its British Association screw thread, both for diameter and pitch. (This should properly be called "lead" because it is the distance between threads instead of the number of threads per unit of measurement, as in the English system.) In addition, this thread has the unusual angle of 47 1/2°, this being developed by Prof. Thurg of Geneva for the Swiss watch industry, and has also been used to some extent in this country by watch factories.

Watch and instrument makers in the United States are also using, and standardizing, a system of screw threads with diameters, threads and tolerances in millimeters, with translations into inches. Motor-car and airplane-engine builders are using spark plugs with metric threads, new standards now being announced by the SAE. Some British automotive builders are also using metric dimensions in other parts of their engines and possibly elsewhere, this presumably in the interest of Continental and other trade. And look at our ball-bearing dimensions!

We formerly boasted that as long as Britain and the United States adhered to the English inch as a basic measurement, it mattered little what the rest of the world used, as our two countries built the great majority of machine tools and other machine equipment. With both Great Britain and ourselves using more and more of the metric units, our arguments as to the superiority of inch measurements are beginning to fall rather flat.

WORLD PREFERENCE

We are still the world's largest builders of production machinery and are likely to remain so. But with the unmistakable trend toward metric measurements, it may be wise to give the matter far more careful consideration than we have done in the past. There are few countries on the globe which are not, theoretically at least, on a metric basis.

There seems to be no vital reason why we should have adopted metric spark plugs in our internal-combustion engines. It would have been easy to make a similar plug of almost the same dimensions to inch measurements. By adapting the metric we gave the advocates of that system one of the best arguments for its general use. They can say, and with logic, "Why not use the same system on the other parts and avoid the confusion due to having two standards of measurement?" Perhaps the greatest argument would be that of making it easier for us to capture a larger share of foreign markets. The smaller manufacturers of other countries now find it easier to secure orders from abroad than do ours—because other countries use their standards of measurement.

This is a problem that requires long and painstaking study; it is a serious undertaking to change from one system to another. It is not a mere matter of translating from inches to millimeters by multiplying by 25.4, the accepted conversion relationship. The actual ratio runs into a long decimal which cannot be dropped if accurate tolerances are to be maintained. In fact, many consider the acceptance of the 25.4 ratio as altering the standard.

NEW DRAWINGS

Should it be decided to take the drastic step of abandoning the inch for the metric system, most manufacturers will doubtless prepare new drawings, giving dimensions in even millimeters instead of trying to handle dimensions with a long string of decimals. The new drawings need not be materially different from those now in use and can maintain nearly the same proportions, but it will mean new drawings, new fixtures, tools and gages and run into millions. Whether it will be worth the cost or not depends on how much new business may result, or even how much of their old business can be retained without it.

It is not a question of the relative merits of either system. That leads to endless and largely futile argument. The problem is rather whether it will pay to have a uniform system of measurement not only for its effect on trade, but also to prevent loss and confusion due to having two systems in use.

Nor can we rely too much on logic. We have a perfectly good decimal currency, coupled with a system of weights and measures that is illogical and confusing. Britain is using the metric or decimal system more largely than we are, but clings to a currency as illogical as our pints, rods and chains.

In Favor of the Metric System

JOHN KIERAN

I HAVE long been furiously in favor of abolishing yards, feet, inches, gills, hogsheads and the whole hodge-podge and clap-trap collection of clumsy units and improper fractions thereof that we call our "system" of weights and measures. I'm all for the sensible decimal or "metric" system.[1]

In answer to a letter of June 27, 1946, from J. T. Johnson, President of the Metric Association, Mr. Kieran said further:

I'm sure we will have to come to the metric system before long, but I hate to see us trailing where we should be leading.

Reports

A Survey on the Use of Metric Measures*

J. T. JOHNSON

THE question of using metric measures in this country has been up for consideration from time to time in our history. At different periods it has been debated pro and con in various newspapers of the country. Metric bills have been before Congress, the last one appearing in 1926. At that time over 105,000 petitions urging metric adoption had been sent to the Congress of the United States.

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[1] Reprinted from *This Week* Magazine, April 16, 1944. Copyright, 1944, by the United Newspapers Magazine Corporation. By permission of the publishers and of John Kieran.

* Reprinted from *Official Report*, 1936 Meeting of American Educational Research Association, St. Louis, February, 1936.

THE QUESTIONNAIRE

To get more recent information as to current public opinion on this question the writer prepared the following questionnaire, which was sent to some 650 manufacturers, engineers, doctors, and educators during 1936:

1. Do you believe it would be of ultimate advantage to the United States to use metric weights and measures
   a. in manufacturing? Yes No
   b. in buying and selling? Yes No
   c. in trade with other metric countries? Yes No
   d. in the elementary schools of the United States? Yes No
2. Do you believe that if the United States were given ten years in which to make the change, the adjustment could be made without any great inconvenience
   a. to the manufacturer? Yes No
   b. to the buying and selling industry? Yes No
   c. to foreign trade? Yes No
   d. to the elementary schools? Yes No
3. If you are favorable to making the change, do you think the best way to effect the change is
   a. through government legislation? Yes No
   b. through education and use in the schools? Yes No
   c. through both *a* and *b* above? Yes No

It will be noticed in Table I that the highest percentage (94 per cent) of the favorable votes in any column is under 3 *b*, which deals with the question of education and use in the schools. That this is not due to the influence of the educator group is brought out by the fact that when the manufacturing groups alone are considered the total vote on this same item, 3 *b*, is: yes, 91 per cent; and no, 9 per cent.

It should be remembered that Question 3 was supposedly to have been answered by only those who favored the cause, but what actually happened was that many who had answered negatively on the other items under Questions 1 and 2 expressed their opinion by answering also items under Question 3.

When the four items under 1 are taken together, the vote is: yes, 80 per cent; and no, 20 per cent. When the four items under 2 are taken together, the vote is: yes, 75 per cent; and no, 25 per cent. The items under Question 3 cannot very well be taken together. The summary by groups (Table II) shows a more interesting result.

Taking the above group as a whole and also the responses of several individuals who replied favorably by letters, the ratio of the yes to no vote is about four to one. Among the manufacturers alone the ratio is about two to one. Among the educators it is about ten to one. Among the doctors and engineers it is unanimously in favor.

It is not contended that the above results tell the complete story of public opinion on the metric question. Because of lack of facilities to canvass all groups, representative groups were selected. For fear of not getting a true random sampling the following groups who may have been unduly weighted towards favorable reaction were purposely left out: the mathematicians, the physicists, the chemists, the various science groups, the pharmacists, the druggists, and the physical education groups—all of which groups are almost universally in favor of metric measures.

That the 391 manufacturers circularized represent a random sampling of manufacturers is quite certain in that the 189 miscellaneous group of manufacturers who were circularized in the spring of 1936 gave returns similar to those of 202 manufacturers who were canvassed later in the fall of 1936. The results from the former group were: yes, 69 per cent; no, 31 per cent. The results of the latter group were: yes, 64 per cent; no, 36 per cent. It is felt that the manufacturing group is the most important group as it gave the most opposition to the metric movement when the last bill was up before Congress. The greater number of questionnaires was sent to that group.

It is interesting to note from the table that the unidentified group whose individual names could not be identified from the firm names which were canvassed gave about the same result as the group as a whole: yes, 77 per cent; no, 23 per cent; whereas the whole group gave: yes, 77.6 per cent; and no, 22.4 per cent.

PEDAGOGICAL IMPLICATIONS

By and large it may be said that current opinion is in favor of metric usage. Since some fifty-five countries of the world are on

TABLE I. TOTAL YES AND NO RESPONSES ON EACH ITEM IN QUESTIONNAIRE

	1							
	a		*b*		*c*		*d*	
	No	Yes	No	Yes	No	Yes	No	Yes
Number of responses	32	105	33	103	15	116	29	105
Per cent of total responses	23	77	24	76	11	89	22	78

	2							
	a		*b*		*c*		*d*	
	No	Yes	No	Yes	No	Yes	No	Yes
Number of responses	46	78	41	85	17	107	20	108
Per cent of total responses	37	63	32	68	14	86	16	84

	3					
	a		*b*		*c*	
	No	Yes	No	Yes	No	Yes
Number of responses	16	46	3	51	9	84
Per cent of total responses	26	74	6	94	10	90

TABLE II. DISTRIBUTION OF YES AND NO VOTES ON QUESTIONNAIRE BY GROUPS

	Number of Questionnaires		*Number of Replies*		*Per Cent of Replies*	
	Sent	Received	Yes	No	Yes	No
Manufacturers						
Die and foundry	29	11	25	49	34	66
Can	35	12	48	40	55	45
Electrical	54	19	69	46	60	40
Miscellaneous	189	38	209	95	69	31
Automobile	28	7	30	11	73	27
Chemical	56	14	101	7	94	6
Total manufacturers	391	101	482	248	66	34
Educators						
Superintendents of schools	100	26	185	24	88	12
University presidents	100	32	273	19	94	6
Total educators	200	58	458	43	92	8
Doctors	12	6	34	0	100	0
Engineers	16	4	37	0	100	0
An unidentified group	...	10	70	21	77	23
Grand total	619	179	1081	312	77.6	22.4

a metric basis, this being true of all of the important countries except those of the United States and the British Empire, and since the standard of length in the United States is the meter, it is thought advisable to acquaint the young student in our schools with at least the meter and centimeter. This will cause no hardship on the school as these measures can be put into every classroom if they are not already there.

An illustration may strengthen the reason for this belief.

In a report recently given by Charles F. Brooks, professor of meteorology at Harvard University, it was stated that in an aviation school in the East the students were given the heights of their ceilings in meters and speeds in kilometers. The students reported back that they could not think in terms of meters and kilometers. As a result, the heights and speeds had to be given in yards and miles. Because these men had not been given the simple information about the metric system they had to take a backward step to the old system when the simpler system could have been adopted by them.

Someone may ask, "What are the advantages of the metric system over the present system in use in this country today?"

There are three distinct advantages of the metric system. For the sake of completeness they will be reviewed here briefly.

1. *Simplicity.* When we compare our fifty-three concepts and terms with which we have to become familiar in the English system of weights and measures to the three simple terms, *meter, liter,* and *gram,* which constitute the metric system, this advantage is at once evident.

2. *Decimal division of its units.* This advantage is so great that it has, to a certain extent, been adopted by the English system. The fact that mechanics has decimalized the inch, engineering has decimalized the foot, and aviation has decimalized the mile, is evidence. We read in the daily paper that the average rainfall was 3.6 inches, that Cairo has a 59.7 foot tide but refuses to worry, and that the average speed of a trip by air was 189.43 miles per hour.

The advantage of this principle inherent in the metric system was brought out in an actual experience recently in a seventh grade room of a Chicago school. The class was studying areas, and in order to get firsthand experience it was measuring the length and width of the blackboard. The dimensions came out: $l = 12$ feet 8 inches, and $w = 3$ feet 11 inches. The teacher did not know whether it was better to change all dimensions to inches or to feet and fractions. Either she could use 47 × 152 and call the answer square inches and then change back to square feet, or she could use 3 11/12 × 12 2/3 and get the answer directly in square feet. The writer has seen many teachers use the latter method in this form, 47/12 × 38/3, getting the awful fraction (improper!) 1,786/36, then dividing to get the final result.

Either method is clumsy and never used by an intelligent adult. The teacher in question had some knowledge of approximations in measurement and got around a big difficulty by writing each dimension in feet and tenths as 3.9 × 12.7 and obtained a close enough approximation for all practical purposes.

Had the students in this class been enabled to measure the dimensions directly in units and tenths, they would have avoided another operation in this problem, that of changing the fractions to equivalent decimals. This very facility is offered by the metric system in that all of its units are divided into tenths right on the instrument with which one measures.

All measurements are approximate, and the approximations depend upon the degree of accuracy with which one wishes to measure. Degrees of accuracy are measured in terms of significant figures, and significant figures can be ascertained in terms of decimals only. There are many reasons why decimals should be used in preference to common fractions.

3. *The interrelation between the units of length, capacity, and weight*—The third advantage, that a unit of capacity shall have unit dimensions and shall have a corresponding unit of weight, is illustrated by the cubic centimeter of water, which weighs exactly 1 gram. There is no such correspondence in the English system. One cubic foot of water does not have a corresponding unit of weight; the best we can say is 62.4 pounds. This causes much computation when one finds weights of tanks or boxes filled with certain commodities when dimensions are given in the English system.

The writer is of the opinion that the student in our schools has the right to find out that there is such a system as the metric system and what the advantages of it are. He has this right just as much as he has the right to hear beautiful symphony music, although that is not the music of the stage or screen. He has this right just as much as he has the right to character training that is sanctioned by the best society, although many acts of adults do not carry out what that training teaches.

The student in the sixth grade can be made centimeter-conscious without any effort. In fact, he enjoys it. All he has to do is to look at the other edge of his ruler and use it a few times. It is much easier to measure to the nearest centimeter than to the nearest half inch. In the seventh grade he can become conscious of the meter and use it in measuring distances and his own height. In the eighth grade he may be made kilometer-conscious. Teachers will have to become metric-conscious first.

A word of caution is apropos here, since the method of teaching the metric system in the past missed its mark entirely. The student should never be asked to convert a metric measure to an English one or vice versa. This will never show him the advantages of the metric system. That was the mistake of the past. He should do the computations directly in the metric system itself and thus learn its simple computations of merely shifting the decimal point to the right or left. This has the same benefits as learning a language by the direct method. It is much better to learn to think in French than to first translate the French into English and then think in English. Likewise it is better to think in terms of centimeters and meters than to first translate these into inches and yards.

Whether you believe that the metric system should be taught in the schools or not depends upon the assumptions upon which you base your belief. Your assumptions depend upon your philosophy. If your philosophy is that of the status quo perpetuator then you will not want the metric system in the schools. If your philosophy is that of bettering the status quo you will want the children to know about the metric system. Your philosophy is your own private affair. This article merely sets forth a point of view of a believer in the philosophy of improving the status quo. And simplification is a method of improvement at the present time.

Uniform Weights and Measures*

The Council considers it desirable to promote unification of weights and measures throughout the Hemisphere on the basis of the metro-decimal system. It has not been possible to obtain such standardization up to the present because of the hold of the old Spanish, English and Portuguese units, in spite of the official adoption of the metro-decimal system in the Latin-American countries.

The Council therefore recommends:

That National Sections proceed to publish or have published the equivalents of the weights and measures of the metro-decimal system with the traditional ones of their respective countries, as a means of facilitating the progressive application of the former.

Newspapers

Metric System Urged for U. S.†

Chicago, March 23. Two years of elementary arithmetic could be eliminated from the grade-school program if the United States would adopt the metric system of measurement, according to Dr. J. T. Johnson, president of the Metric Association.

Dr. Johnson, who is chairman of the mathematics department of Chicago Teachers College, pointed out that textbooks now spend three times as much space on common fractions as they do on decimals.

"Fractions could be almost completely disregarded as a factor in arithmetic if the metric system were adopted," he said.

"Instead of the present system of pounds, feet, inches, rods, acres, and the various other unit designations now in use, we would have only three units to worry about. Everything in the system is based on the meter, the liter and the gram. The whole thing can be taught in a few hours to an eighth-grade pupil."

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* Reprinted from "Policies Adopted by the Second Plenary Meeting of the Permanent Council of American Associations of Commerce and Production," Washington, D. C., May, 1944, by permission of the United States Inter-American Council.

† Reprinted from the *Seattle Times*, March 24, 1946, by permission of the publishers.

Dr. Johnson said that nearly everyone is in favor of adoption of the system after he finds out how simple it is.

"In the measurement of length, for instance, the smallest unit, the millimeter, and the largest, the kilometer, are based on the standard meter. To convert from one to the other, all you have to do is move the decimal point.

"It's a different story, though, when you try to convert inches into miles or rods."

More than 75 per cent of the world's population uses the metric system now, Dr. Johnson said, and many American business men who carry on trade with South America or any other country in the world outside the British Empire have to use metrics.

"The American Medical Association and most pharmacists use the system because it is much more convenient," he went on, "so the issue is not between use of the English system as opposed to the metric. We use both systems now.

"The question is whether we are going to continue using both or adopt the one simple system."

War and the Metric System*

THIS isn't precisely a new editorial, so far as this paper is concerned. We've run substantially the same editorial once or twice before; maybe oftener. But it's always a true editorial, and if enough other papers and private citizens all over America would repeat its substance often enough and loudly enough we might achieve some important progress.

RECKONING BY DECIMALS

This one is about the metric system of weights and measures and how seriously we need to adopt it, at the same time tying the can to our present mismesh of feet, pounds, quarts, statute miles nautical miles, acres, short tons, long tons, and at least three kinds of ounces.

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* Courtesy of *The News*, New York's Picture Newspaper, December 26, 1944

As several millions of us find every time we get into a war and run into the metric system used by many other countries, the metric system is far superior to the system to which we and the British cling with such pride and tenacity.

In the metric conception of weights and measures, everything goes up or down by tens—a true decimal system. All measurements of length and area, and all volumes expressed in line measurements are based on the meter; all measurements of mass, on the kilogram.

We all know how simple it is to count U. S. money. This is because we reckon our money by a decimal system. We could measure everything else—distances, areas, weights, volumes, of all kinds—with equal ease and simplicity if we would adopt the metric system.

A beginning was made toward U. S. adoption of metrics in World War I. Many American fighting men in France were impressed with the metric system's scientific simplicity, and learned how to read maps with metric scales.

Since then we have adopted metric measurements for some of our Army guns—55-millimeter, 105 mm, 155 mm, and so on—and that is all to the good. The Navy, however, clings to its 6-inch, 8-inch, 16-inch, etc., guns. Metric and inch ammunition not being interchangeable, it is interesting in a grisly sort of way to imagine what might happen some day if Army and Navy units were cooperating in some serious fracas and one or the other happened to run out of ammunition.

LET'S GO METRIC

Why not grab this opportunity for change and improvement which this war presents, and get the United States well started during the war toward general adoption of the metric system for both civil and military activities?

The Government could contribute a husky push by requiring that all specifications in war supply contracts be stated metrically;

and another by using the metric system generally in the training camps. It could also require that all its blueprints for big public works projects after the war be started in metrics.

With 10 or 12 million of our most vigorous young men acquainted with the metric system and its advantages over the old one, the whole country's conversion to metrics ought to follow fairly fast and we'd have gained one advantage, at least, out of a war which does not yet promise to yield us many advantages.

In measuring temperature, we are behind the times, too, so long as we cling to the Fahrenheit thermometer, with its placing of the freezing point of water at 32 degrees, of normal human body temperature at 98.6, and the boiling point of water at 212.

SCIENTIFIC CENTIGRADE

Not that old Dr. Gabriel Daniel Fahrenheit (1686-1736) of Danzig wasn't a true scientist when he invented his thermometer; he was. He put his zero temperature at the lowest degree of cold obtainable with a freezing mixture of ice and salt, then divided the difference between this temperature and human body temperature by 12, and later by 96. That made freezing temperature come out at 32 and boiling at 212; and the whole performance was good scientific procedure for Fahrenheit's time.

His time was a long time ago though. Now we have the simple, coldly scientific decimal thermometer that goes by the name of centigrade. It calls water's freezing point zero, and its boiling point 100. Living in an era of science and priding ourselves daily on same, it seems 'passing peculiar that we don't adopt this scientific thermometer along with the rest of the metric system.

We Could and Should Adopt the Metric System[*]

WE COULD and should adopt THE METRIC SYSTEM of weights and measures as standard for the United States, and we should throw out the foot-pound-quart system as fast as feasible.

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[*] Courtesy of *The News,* New York's Picture Newspaper, January 1, 1946.

Our present jumble, inherited from England, of inches, feet, yards, miles, ounces (troy and avoirdupois), pounds, tons (short and long), pints, quarts, fifths, magnums, jeroboams, cubic inches, cubic yards, pecks, bushels, etc. is just that—a fantastic and unscientific jumble.

In opposition to that jumble since the year 1790 has been the metric system, worked out by French Revolutionary scientists, and now in use throughout most of the world except the United States and the British Empire. Even in the English-speaking countries, the metric system is widely used by scientists and in certain industries, and to some degree by military and naval men.

MEASURING BY TENS

The metric system is a decimal system, meaning that it proceeds up and down by 10's, just as our money does. This simplicity extends through all kinds of measurement—distance, length, volume, weight. There is no guesswork about it. Ten for some reason—perhaps because normal persons have 10 fingers—is the easiest figure for most people to use in multiplying or in dividing.

To round out this reform, we should also adopt the centigrade thermometer, which is a true metric thermometer. It starts at zero as the freezing point of water and proceeds to 100 as water's boiling point, rather than from 32 to 212 as on the old-fashioned Fahrenheit.

President Truman could start the New Year right by gathering together a commission of scientists, teachers, military men and naval men to study the various aspects of a general United States changeover to the metric system, and make recommendations within a reasonable time. Congress and the assorted Government departments—especially the Navy and War departments—could then start the metric ball rolling in a concerted and determined way.

By engineering such a reform, the President would do this generation a great service, and succeeding generations of Americans an even greater one.

To Press Adoption of the Metric System*

Groups in Science, Education, Business and Industry Back Campaign for America

CHICAGO, February 16. Supported by scientific, educational, business and industrial groups, a nationwide campaign is contemplated to put the United States on the metric system of weights and measures.

Dr. John T. Johnson, president of the Metric Association and head of the mathematics department of Chicago Teachers College, said today that plans to extend the system not only to this country but also to Great Britain would be discussed at a special session of the association here next summer.

As at the end of every major war since France adopted the system at the end of the French Revolution, he said, a flood of inquiries about it had come. He recalled that Turkey, Japan, China and Russia accepted it in 1920-21 and pointed to its present use over the world except in the United States and Britain.

QUESTION OF STEPS TO TAKE

Members of the association are divided as to the best method for getting the metric system adopted in the United States. Many advocate Congressional action, but, because of the defeat of legislation in 1922 and 1926, others favor taking the cause to education executives of the States.

Pointing out that the metric system was legalized by Congress in 1866 and that in 1893 the meter was made the standard of length for the United States, but that the country as a whole had never adopted it, Dr. Johnson said:

"The Government has done its part, and it has no direct control over education. It is up to the States to put it over."

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* Reprinted from the *New York Times*, February 17, 1946, by permission of the publishers.

If legislation were defeated again, he warned, it might take a generation to educate the people on the values of metric weights and measures. Regarding current interest, he noted that many of the inquiries came from business and industrial organizations which had previously been averse to the change because of its cost.

APPLICATION OF THE SYSTEM

Adoption of the system, he said, would eliminate two years of instruction in arithmetic and qualify school graduates for jobs in business and industry which apply it where decimals are used instead of fractions.

On this point, Dr. William H. Johnson, superintendent of Chicago schools, declared that the metric system was better than the English because it was easier to teach and to learn, it simplified mathematics with all figures in units of ten and contained a direct relation between weight and volume.

The metric system is taught in the eighth grade in Chicago and is used in high school and college science courses, but it is learned as an additional system of mathematics.

The superintendent suggested that its world-wide use would be "a long step in world cooperation toward peace."

VIEWS OF LEADING SCIENTISTS

Dr. Harold C. Urey, the discoverer of heavy water, and Dr. Enrico Fermi, a pioneer in the atomic chain reaction, who worked on the atomic bomb research at the University of Chicago, agreed that use of both the English and the metric systems "complicated" the project.

Arthur Jaffey, acting chairman of the atomic scientists of Chicago, said that his group was 100 per cent for adoption of the metric system.

On the other hand, Dr. Ovid W. Eshback, dean of Northwestern University's Technological Institute, maintained that both the English and the metric systems were needed for the convenience of Americans as each had its merits.

This Is the Year MCMXLV[*]

The ancient Romans had a lot of sound ideas and efficient practices, especially in fighting by land or sea and then governing the territories they conquered.

When it came to numbers, though, their system left a lot to be desired. It was about as cumbersome an affair as could be imagined.

It was a complex of I's, V's, X's, L's, C's, and so on, so that every number you wrote called for a confusing juggle of these symbols—except that by drawing a straight line over a numeral you could indicate that it was multiplied by 1,000.

According to Roman numbering, this year of 1945 is MCMXLV—and a pretty short and snappy designation compared with some numbers that can be doped out in Roman numerals. The year 1899, for example, in Roman numbers was MDCCCXCIX. The Civil War ended in MDCCCLXV, or 1865; we declared our independence of Great Britain in MDCCLXXVI, or 1776.

The Encyclopedia Britannica assures us that adding numbers the Roman way was simpler than our way, giving the following example:

DCCCCLXXXXVIIII	999
CC XXV	225
MCC XX IIII	1224

We'll take the Britannica's word for it that that is a simple operation; guess we're just too dumb to follow it. We note, though, that the esteemed reference work is more than vague—in fact, it doesn't utter—on how the Romans multiplied and divided in their mathematical sign language.

Came the 10th Century A.D., and the Arabic numerals were introduced into Europe. These are the numerals we use today. Their Arabic inventors had had the brilliant inspiration, too, to devise a numeral to signify nothing—zero—which had never occurred to the Romans.

The advantages of Arabic notation over Roman are obvious.

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[*] Reprinted from the *Times-Herald*, Washington, D. C., May 31, 1945, by permission of the New York News Syndicate Co., Inc.

These numerals furnish a vehicle for swift, clear reckoning of all kinds. It is believed by some thinkers that the prehistoric invention of the wheel was the greatest single invention in man's history. We think the invention of Arabic numerals was also of primary importance.

There is another invention which in the field of measurements has a vogue comparable to that of Arabic numerals in the field of reckoning.

We're talking about the metric system, in contrast to the foot-pound-quart system in use today in the United States, the British Empire, and nowhere else that matters much. Most of the rest of the western world long ago adopted the metric system, devised by French scientists in 1790.

The metric system moves up and down by 10's; it is a decimal method for measuring length, area, volume and weight.

In World War I, a lot of our fighting men ran into the metric system in operation in France, and saw how simple it is. After that war, metrics hung on to some extent in our armed services, especially as regards reckoning Army gun sizes. The Army nowadays has its 20-millimeter guns, 37-mm's, 57-mm's, 105-mm's, and so on—though, curiously enough, its artillery fire control mechanisms mainly operate on the feet-inches system.

The Navy, on the other hand, sticks to gun calibers measured by inches—6-inchers, 8-inchers, 14-inchers, etc. Why can't the boys get together? There must be occasions where it would be most convenient if Army and Navy units in joint operations could swap ammunition.

One force that could do a lot to bring the boys together is President Harry S. Truman. Mr. Truman in World War I was captain of Battery D, 129th Field Artillery, 35th Division, a division which saw considerable activity in France. In that capacity, Capt. Truman had ample opportunity to see the advantages of the metric system over any other.

As Commander in Chief, Mr. Truman could give the country many a nudge toward complete adoption of the metric system, in both military and civil life. He could start the Navy toward metric gun sizes, at a safe speed; could press for the drawing of all our military maps and war contract specifications in metric terms;

and so on. Once the armed forces went all metric, the civil population would be likely to do the same . . . and thus President Truman would have performed a great service to all Americans.

Britain Going Metric?*

THE Association of British Chambers of Commerce have adopted a resolution urging the metric system for Great Britain and recommending appointment of a government committee to consider the changes. They have also advocated a change in British coinage to a decimal system. Britain is the only European country without a decimal system of coinage and measurement. We all know how simple and easy it is to count U. S. money. That is because we reckon our money by a decimal system.

We have long advocated the metric system for this country in contrast to our present foot-pound-quart system, which is in use today in the United States and Britain and nowhere else in the world that matters much. The metric system moves up and down in 10's. It is a decimal method for measuring length, area, volume and weight. After World War I, we adopted metric measurements for some of our Army guns, such as 155-millimeter, 105 mm, and so on. The Navy still clings to its 6-inch, 8-inch, 16-inch, etc. guns.

The metric is indeed a good idea. We ought to adopt it, not only for money, but for thermometers, weights and measures, etc.

The resolution which follows was introduced by Harry Allcock, Chairman of the Council of the Decimal Association of England.

"Having regard to the vital national importance of export trade expansion and to the consequential need for the improvement of our trading methods by all available means, the Association of British Chambers of Commerce considers it essential that British traders should employ a decimal system of coinage and the metric system of weights and measures of which the higher efficiency, as compared with the British systems, has been demonstrated in so many countries for so many years. In view of the technical nature of these proposals, it is suggested that the Government should set up an appropriate committee (or committees) to recommend the most convenient means of securing the desired objects."

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* Reprinted from the *Times-Herald*, Washington, D. C., October, 1945, by permission of the New York News Syndicate Co., Inc.

Metric System*

THAT caption is old, and boring, no doubt, to some people; and it seems a safe bet that some of the customers will stop reading these remarks at this point.

Nevertheless, the metric system of weights and measures is as great an improvement over the foot-pound-quart system as Arabic numerals were over Roman. If you don't realize what an improvement Arabic numerals were, try multiplying XIV by XL, and then do it in Arabic—14 × 40.

Further, we already have a metric system for measuring our money—cents, dimes, dollars, with the in-between nickels and quarters entirely logical and understandable. We wouldn't think of going back to the British reckoning of pence, six pence, shilling, florins, pounds, and guineas, with which our colonial ancestors struggled.

But the great majority of us were born and drug up under the foot-pound-quart system, and human inertia is such, even in the dynamic and generally progressive United States, that the agitation for adoption of the metric system in this country makes only the slowest headway. It has penetrated into the electrical and optical businesses, to some extent into the Army, and to a lesser extent into the Navy; but that's about the best news that can be offered up to now, though the metric system itself was devised by French scientists in the year 1790.

If President Truman wants to do something constructive for his country, and even more so for our children and theirs, he can appoint a commission to look into the problems connected with a general changeover to metrics. On this commission could be various scientists, military men, business men, professors. Encouraged by the report such a commission would be likely to turn in, Congress might grease the wheels for a change to metrics. If it should, it would do all Americans a service of the first magnitude.

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* Reprinted from the *Times-Herald*, Washington, D. C., December 17, 1945, by permission of the New York News Syndicate Co., Inc.

The Metric System[*]

WAR BRINGS US NEW LIVING AIDS

THE war has brought a lot of new substances and devices into what is often called the American way of living. There are lifesaving penicillin, malaria-fighting atabrine, synthetic rubber, nylon, radar (which everybody says is going to revolutionize commerce, industry and everything else when the war is over), faster and more powerful planes, improved methods of surgery and psychiatry and countless other items on the credit side of the war ledger.

We might have had a lot of these things eventually anyway, but the needs of a nation at war have speeded up their development so that we can hope to enjoy them to the full when the hostilities are over.

But there is one thing the war might have done for us which it has not. The war has not brought about the national use of the metric system of weights and measures.

Big dictionaries contain a table of weights and measures that has some wonderful names in it. There are ten poods in a berkowitz in Russia, and 25 miskals in an abbas in Persia. There are 12 inches in a foot in the United States. And while that may not look funny to us, we do have some others that are peculiar, to say the least. Pecks, hundredweights, pennyweights, hands, hogsheads and so on, all arbitrarily set maybe hundreds of years ago.

Our Army has 155-millimeter guns and our Navy has 6-inch guns. We have 75s and 3-inchers. We have .50-caliber machine guns, based on inch measurement, and 37 mm guns based on metric measurement. The British are not much better off than we are, with their stones, imperial quarts, ells and so on.

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[*] Courtesy of *The News*, New York's Picture Newspaper, July 24, 1944.

But there has been a perfectly good system of weights and measures lying around for 150 years, since it was adopted in 1795 by the French. It took a revolution to change the French, at that.

The metric system is based on the meter, which is taken to be one ten-millionth of a quadrant of the earth; the liter, which is the volume of a cube one-tenth of a meter on each side; and the gram, which is the weight of one-thousandth of a liter of water at 4 degrees centigrade.

SYSTEM ADOPTED BY SCORE OF NATIONS

The metric or decimal system has been formally adopted by a score of countries. It has been tolerated in England, Japan, Russia, Turkey and the United States. In England a battle raged for years as orderly-minded people agitated for its adoption. It wasn't until 1897, in fact, that the law against possession of a set of metric weights and measures was repealed in England.

In this country we nearly adopted a decimal system of weights and measures thought up by Thomas Jefferson, but something happened to it and we merely took over the English methods, although somebody was smart enough to set up our money system which is the easiest in the world to count and handle because of its simplicity.

In the last war American soldiers in France found the metric system convenient and workable. That is why we now have, in addition to guns measured by inches, caliber or gauge, others which are designated by their millimeter size.

Our soldiers are back in France and more of them will be introduced to the simple French system as they march for kilometers, drink liters of wine and buy kilograms of flour.

SCIENTISTS KNOW VALUE OF THE METRIC SYSTEM

At home here, while industrial measurements are still on the inch basis, more and more precision instruments are calibrated metrically and a good many scientific laboratories use the metric system. Workers in those lines are used to precision and order and know the value of modernizing their procedure.

Our Bureau of Standards possesses master metric measurements as well as masters of the inch and pound system. A good many of our large cities also are supplied with master measures of both kinds.

There is no really good reason why the changeover to the metric system could not be made throughout our whole domestic scene. All the things we make and wear and eat, machine work, yard goods, coal, oil, butter, prescriptions, potatoes, could be bought and sold under the metric system. At least one confusion could be eliminated from our economy if we were to reduce our weights and measures to the modern simplicity of our monetary system.

Metric System's Universal Use Urged as Step to World Peace*

JOHN J. O'NEILL

A COMMON language throughout the world would be one of the most effective aids in achieving and maintaining peace and maximum cooperation among nations. Scientists have a kind of universal language, actually two such languages, mathematics and the metric system, their language of measurement.

It is easily possible, and highly desirable, for the entire world to adopt the metric system. It provides the simplest, most adaptable, most easily used, most highly coordinated and most universal system of measurement.

MONEY CONTRASTED

In order to grasp quickly the advantages provided by the metric system, it is necessary only to compare the money system of the United States with its dollars, dimes and cents with the English system using pounds, shillings and pence, plus variants, such as guineas and crowns. Ten cents equal one dime, ten dimes equal one dollar and ten dollars one eagle. In English money twelve pence equal one shilling and twenty shillings equal one pound.

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* Reprinted from the *New York Herald-Tribune*, November 3, 1946, by permission of the publishers.

The millions of American soldiers who passed through England during the war were confused by the pounds, shillings and pence of that country, and enthusiastically chided the English for continuing to use such an archaic system. They were unmindful, however, that our system of weights and measures is just as archaic, and dates back to the length of the royal nose, or foot of Percy the Unteenth, or other unscientific standards.

The number system in use throughout the world is decimal, that is, it uses 10 as its base. Our money system is decimal and so is the metric system in all of its units of length, volume, area and mass, or weight. All of the metric units are derived from a single unit, the meter, the unit of length.

USES NATURAL STANDARDS

This unit of length is tied to natural standards in two ways. By original definition the standard meter is one ten-millionth part of the distance between the equator and the pole measured along a meridian. Later calculations indicate the adopted standard is inaccurate by an extremely small amount. By a more recent definition the meter is a multiple of the wave length of a particular red line in the spectrum.

The meter corresponds closely to our yard. It is almost 10 per cent longer. One meter equals 1.094 yards, and one yard equals 0.914 meter. Our yard is divided into thirty-six inches, a relic of the sexagesimal system of counting used in Sumeria more than 4,000 years ago. The meter is divided into 100 units called centimeters, just as our dollar is divided into 100 units called cents. A common division of our inch is into eighths. The centimeter is divided into tenths called millimeters, which are thousandth parts of a meter. The larger unit of length is the kilometer and contains 1,000 meters. The kilometer is a little more than a half (0.621) mile, and a mile equals 1.61 kilometers.

The centimeter is the base of the unit of volume and of weight. One thousand cubic centimeters make one liter, which closely approximates the standard United States liquid quart. A liter of water weighs one kilogram so one cubic centimeter weighs one gram.

SYSTEM WIDELY USED

Practically all of the continental European countries and the South American countries use the decimal metric system in all commercial transactions and its use is legally permissible elsewhere throughout the world, including the United States. A standardization of containers and measurements on metric units would greatly facilitate world trade. There is always a sense of mistrust when a diversity of units of measurements is used, and a sense of understanding when all talk the same language of measurement.

Now is the ideal time for making such a shift, when the world is trying to reach a new basis for international agreements. Universal use of the system in this country would be a great aid to understanding and doing business with the metric countries of Europe and also those in South America.

An even greater advance in laying a solid foundation for peace and good will among nations, and more particularly for mutual understanding among the peoples of the earth would be a universal metric system of coinage with a standardized unit of value. Through this international money operations could be reduced to a basis that would permit the average man to understand what was being done much more easily than by figuring the exchange rates among a great many different currencies.

STEPS BEING TAKEN

Steps leading to a system of international standards are being taken at a meeting in London being attended by delegates from the American Standards Association and the British Standards Association and delegates from many other countries. P. G. Agnew, vice-president and secretary of the A.S.A., and E. C. Crittenden, assistant director of the National Bureau of Standards, are representing the United States at the conference.

The American Standards Association, of which many hundreds of industrial corporations are members, takes no stand in the matter of setting up standards, but provides the mechanism by which there can be defined and set up for use any system or standard desired by its members. Some members requested an inquiry be made into the desirability of adopting the metric system for describing adopted standards in conjunction with the common English units. A committee appointed a year ago is now investigating the problem.

The Metric System and the Postwar World*

J. T. JOHNSON

WAR hastens trends and precipitates change!

World War I brought about many changes in science, industry, and medicine. As a result of the tremendous development of the airplane, this war will make our world much smaller, socially and commercially. International trade will be stepped up. This will call for simplified practice in international business transactions. We cannot afford to have three number systems in each of which the principles of operations vary.

Our children are now forced to learn three different systems: the whole number system where the decimal principle of place value applies, the common fraction system where different operational principles apply, and the denominate number system where still different principles apply.

What is the present trend of simplification? Everyone will agree that it is toward decimalization of our number system. This is attested by the fact that mechanics has decimalized the inch. Parts of automobiles are made to the ten-thousandths of an inch. Engineering has decimalized the foot. Surveyors measure in feet and tenths, not in feet and inches. Aviation has decimalized the mile. We read of the tremendous speed of a bomber as 350.486 miles per hour. Why is this? The answer is that in decimals the same principle of place value applies as in whole numbers. When Simon Stevin invented the decimal in 1585 he simply extended the principle of place value inherent in our whole numbers to numbers smaller than 1.

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* Reprinted from *Tempo*, Chicago Teachers College, November, 1944.

We count and we measure! These are the two great primitive uses of numbers. Would it not simplify matters if we could use the same principle when measuring as when counting? Is there a trend in this direction? Yes, there is. Ever since France, in 1799, invented the metric system, groups and countries at different times have adopted this system of measurement.

After the Prussian War in Europe in 1871, Germany, Austria, Hungary and subordinate colonies adopted the metric system, almost doubling the population then on a metric basis. In 1866, right after the Civil War in this country, the metric system was made legal by act of Congress. [illegible] in 1893, it was made the standard in the United States. In 1920-1921 after World War I the metric system was adopted for official use by Russia, China, Turkey, and Japan—thus more than doubling the population that was at that time on the metric basis. It is now officially used by fifty-five of the fifty-seven countries of the world and by more than 75 per cent of the world's population.

What is the reason for this trend? The answer can only be, simplified practice. Any one who knows the metric system knows its simplicity. The fact that it lines up everything that is measured in a one-to-one correspondence with our whole number system where the decimal principle of place value applies, accounts for its simplicity.

There can be no stopping of this trend! World War II is bound to give it a boost.

Think of the time and energy that would be saved our boys and girls in school—not to mention the teachers—if the metric system were the official system in this country!

The issue now is not between the English system and the metric system, but it is between two systems now in use with the time-consuming, incommensurable "error-producing" conversions, on the one hand, and one simple "like-our-whole-number" system, the metric, on the other.

Which shall it be?

When Size 9 Is Size 10*

VALE WEBER

Working Out the Differences in British and American Weights and Measures Is Costly —and So Confusing

NOT long ago an altruistic lady living in the Bronx posted a package of clothing to a married sister and her family in England. The parcel contained a pair of shoes, a pair of stockings, a child's dress and a woman's suit. When it arrived, nothing in it fitted. The shoes pinched and the stockings were too short. The child's dress was too big and the suit was too small. The sender's good intentions were completely wasted.

Multiply the Bronx woman's misadventure by a few hundred thousand when postwar transatlantic business really gets under way, express her case in exporters' terms and you get an idea of the millions that are being lost every year in Anglo-American trade because the United States and Britain have not yet thought it worth while to make a serious effort to get together on the bewildering business of international weights and measures.

Almost nothing has the same measurement in New York as in London. Harassed shipping clerks and salesmen spend a large part of their time trying to figure out what sort of man in America could wear a size 6 English suit, how long an American inch is in Manchester, just what an imperial gallon means when poured into an American tank or an imperial pint into an American decanter.

The complications are endless. For instance, the gallon used today in the United States is still the same Queen Anne gallon that the English used—and discarded long ago. Sometimes it measures a pint and a half more than the present English imperial gallon, sometimes less than this. It depends on what is contained in the gallon.

The bottle of whisky known to Britons as a "quart" because it contains one-quarter of their gallon, equals only one-fifth of the American gallon. Whisky proofs in the two countries differ too.

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* Reprinted from the *New York Times*, September 22, 1946, by permission of the *New York Times* and of Vale Weber.

British proof equals 114.2 per cent of United States proof—and contains 57 per cent alcohol. United States proof is 12.3 per cent under British proof—6.15 per cent less alcoholic content to a gallon. This may be one reason for the steady demand for Scotch whiskey everywhere.

Discrepancies are not confined to luxuries and alcoholic stimulants. When American farmers send England a quarter of wheat (eight bushels in England) they have to send eight and one-fifth bushels by American standards—because the American quarter is a fifth of a bushel less than the English quarter. Price adjustments in both countries have to be made.

Congress has never officially decided just how long an American inch is. Our inch has become standardized by use, but it still differs very slightly from the English inch. (A meter equals 39.37011 British inches, or 39.37 United States inches.) Moreover, American manufacturers do not always make their merchandise the same size as that of their competitors. Two manufacturers' sizes 9's or 12's or 20's do not measure the same, and if they did, they would not be the same as the English measurements.

Discrepancies in American and British shoe sizes range from one full size to a size and a half. The British size 5 shoe for women is equivalent to an American 6 1/2. Shoe widths are correspondingly wide—in most instances far too wide for the American foot. Stockings for women and socks for men differ too. The 9-inch English stocking would be anything from 9 1/2 to 10 in the United States, depending upon the manufacturer. In some cases it has equaled size 11.

The story is the same in gloves, in underwear, in hats—in practically everything to wear. Sales clerks shake their heads at the possibility that sizes may not be the same in England. English shop assistants are just as perplexed when told that sizes may not be the same in America.

The war showed clearly how vital it is that there should be some standardization between the two nations. In a machine-age economy, literally held together by screws, the threads of vital screws in the United States and Britain are still different.

Half-way through the war William L. Batt, vice chairman for international supply of the War Production Board, told America that $100,000,000 had been unnecessarily added to the cost of production and repair of machinery up to that time by the simple fact that British and American screws have different numbers of threads per millimeter. In most cases British and American gun parts were not interchangeable, according to Mr. Batt, even though the completed products were of identical design—outwardly.

Tons of paper are wasted by exporters on both sides of the Atlantic in working out differences affecting shipping space, money and time. Yet America and Britain are growing closer together on the business level—especially since the loan—while Whitehall and Washington remain content with shoes that won't fit, gallons that overflow, inches that differ, neckbands that strangle, stockings that are too long or too short. Isn't it time they got together?

Air Metric System Is Adopted by ICAO*

JOHN STUART

Britain and U. S. Lose Fight for Own Measuring Terms as World Standard

MONTREAL, May 26. Countries using the metric system today won a long fight to recommend that system of measurement in air-ground communications. Countries of the British Empire, the United States and Mexico, which use the foot and pound units of measure, bitterly opposed the plan in the Assembly of the International Civil Aviation Organization.

Back of the fight lay the wish of the metric countries to get into the manufacture of aeronautical instruments. Since the war this profitable business has been almost exclusively in the hands of the United States and the United Kingdom, the big aircraft manufacturing countries.

The proposal precipitated a debate lasting three and a half hours. Resolutions and reports from five other commissions of the assembly lay an inch deep, or 25.4 millimeters, on the delegates' desks. They numbered about 250 pages. By disposing of the one page covering the metric system recommendation, the assembly got through one millimeter, or one 25.4 of its work.

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* Reprinted from the *New York Times*, May 27, 1947, by permission of the *New York Times*.

The resolution recommends that the Council adopt as rapidly as possible as an ICAO standards a system of units in ground-air communications and related publications that permits only long distances to be measured in nautical miles and vertical speeds in knots.

Altitudes, elevations, dimensions of airports, vertical speeds, wind velocities, cloud heights, visibilities, altimeter settings, temperatures and weights are to be expressed in the metric system.

The Council will soon adopt this recommendation. Unless a large number of member states object to it, it will become standard. The Council is permitted to provide alternatives in pounds, feet and statute miles for countries where such alternatives are required in the interest of safety.

It is recognized, however, that adoption of the system in the vital field of air-ground communications will have an important effect on the future use of the metric system in all aeronautical dimensions.

Why Not Go Metric?*

THE presence of heroic elements of the U. S. Navy in New York and other ports reminds us of a crusade which has been making only slow headway in this country. We refer to the battle to sell Americans on the metric system, the only truly scientific system of measurement.

ARMAMENT CONFUSION

Here are some essentially ridiculous facts about the weapons with which our sea, land and air forces fought the war:

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* Courtesy of *The News*, New York's Picture Newspaper, October 22, 1945.

The fighting ships of the Navy used big rifles whose calibers were measured in inches—six to 16. Their smaller guns, though, were in millimeters. The army artillery's favorite big weapons were described metrically—155-millimeter, 105-mm, 90-mm, 75-mm. But another favorite army weapon, the deadly "goon gun" or small mortar, used 4.2-inch shells.

Rockets, of which our forces made such effective use in many a bloody beach assault, were of seven main types—and all of these were sized in inches, from 2.25 to 5, and so on.

Our airplane bombs were described in the old-fashioned way —500-pounders, 1,000-pounders, 12,000-pounders, etc.—instead of in the scientific metric way by kilograms. Or they were designated in tons; and when our airmen and the British airmen were plastering Germany together, there was the added confusion of the differing U. S. ton and British ton.

The bazooka, our deadly and extremely modern anti-tank rocket gun, was officially known as the 2.46-inch rocket launcher. Our airplanes were as modern as anybody's and more so than most; but one of their best weapons throughout the war was the .50-caliber machine gun, meaning the half-inch machine gun.

According to Gen. Marshall, our superiority in infantry fire power was never overcome throughout the German war, and it stemmed from the use of the Garand semi-automatic rifle; and this superb weapon, the last word to date in such arms, is sized in the old way, being a .30-caliber job. The Browning automatic rifle is no slouch, either; and it, too, is .30-caliber.

We even mixed old and new measurements on one and the same piece of armament. Gen. Marshall in his recent widely hailed report speaks, for example, of two tanks, "the T-29 and T-30, which weighed 64 tons, one mounting a high-velocity 105-mm rifle, the other a 155-mm rifle."

This confusion ought to be cleared away as fast as may be. We ought to scrap foot-pound measures in the armed services, at least, and put all measurements on a metric basis.

The metric system, with its up-and-down progression by 10's, is as simple as U. S. dollars and dimes when you get the hang of it, which you can do in short order.

METRICS IN THE SERVICES

Large numbers of our men have been fighting in countries using the metric system. They must have learned a lot about it and how to use it.

If the armed services would take to writing all their specifications in metrics, the industries supplying them would have to extend their own knowledge and use of metric measurements, and the reform would gradually spread through the civil population.

Now is the time to get this reform under way. Army and Navy units to our best knowledge were not caught with non-interchangeable ammunition in any crucial engagement of World War II; but such a thing might happen in World War III. Why not insure against it while we're at peace?

While we are about it, we should also do something drastic to the Fahrenheit thermometer, the thermometer most used in the United States and Great Britain.

This curio was invented early in the 18th century by Dr. Gabriel Fahrenheit of Danzig, and on principles that were scientific at that time. Fahrenheit started with the lowest temperature he could get with a freezing mixture of salt and ice, and called it zero. He divided the difference between this temperature and the human body temperature by 96, which made the freezing point of water 32 and its boiling point 212.

SCRAP FAHRENHEIT; ADOPT CENTIGRADE

The centigrade thermometer, however, is completely scientific, whereas the Fahrenheit is only relatively so. On the centigrade, water's freezing point is zero, and its boiling point is 100, and that is all there is to it. The centigrade thermometer goes logically with the metric system, and these two aids to accuracy and speed in all weighing and measuring should become standard throughout the United States.

We pride ourselves on being the world's most scientifically advanced nation, which indeed we are. Why, then, the hesitation—the generations of hesitation—to go completely and sensibly metric?

Radio

Let's Use the Metric System![*]

C. J. ARNOLD

GIVEN over Radio Station KYSM, Mankato, Minnesota, on Tuesday, February 5, 1946, 8:45-9:00 A.M. on the Mankato Schools on the Air Program.

Sound: SCHOOLBELL RINGING (FADE-IN)

ANNOUNCER: (OVER BELL) MANKATO SCHOOLS . . . ON THE AIR!!!

Sound: SCHOOLBELL . . . FADE UNDER AND OUT DURING SPEECH

ANNOUNCER: Good morning, everyone. Welcome again to Mankato High School, for the third in a series of twenty public service broadcasts, telling of education in Mankato's schools. Our host once again is the professor, who takes us to rooms in the school where we may look in on classes in action, listen in to extra-curricular activities, and hear special presentations. The professor is waiting for us already, so let's go in. (PAUSE) Good morning, Professor.

PROFESSOR: (FADE IN) Good morning, Bob, and good morning, everyone.

ANNOUNCER: We're ready once again, Professor, to visit another room, or whatever you have in store for us.

PROFESSOR: On the docket for today is a very important issue.

ANNOUNCER: What's that?

PROFESSOR: Today our visit takes us to the Mankato High School Auditorium, where the students are assembled to witness this broadcast. On stage, a group of boys are waiting to begin a story.

ANNOUNCER: Well . . . what sort of story?

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[*] Quoted by permission of C. J. Arnold.

PROFESSOR: A story that is presented as a means of calling to the attention of the general public a bad situation that exists in present-day American education. It's presented in the hope that it will bring about an enlightened public opinion that will eventually lead to its correction. It calls for a simplification of education. Particularly in the subjects of science and mathematics—two subjects which often cause great difficulty to students and are commonly referred to as "hard" subjects. These subjects are much more difficult than they need to be. Millions of hours of work are demanded of students that could be put to more profitable use. Efficiency, the keynote of our day and age, demands that something be done about it. Right now in the auditorium, the boys are ready to tell our story. So . . . let's look in on Bill Jones . . . busy with his home work. He is confronted with a problem in high school physics.

BILL: What is the weight of a block of wood 4 feet 9 inches long, 2 feet 3 inches wide and 1 foot 11 inches thick? The specific gravity of wood is .6.

(WHISTLES)

Holy cow! That's another humdinger.

Sound: DOORBELL RINGS

BILL: Come in.

Sound: DOOR OPEN AND CLOSE. ENTER HARRY, BOB, AND JOE.

BILL: Oh hello, there, Harry, Bob, and Joe.

HARRY: What are you doing, Bill?

BILL: Oh, I'm working some physics problems for tomorrow. Gotta find the weight of a block of wood.

BOB: Say, talking about weight, I've got a problem for youse guys. Wann' hear it?

JOE: You? You've got a problem for us? ha! You never took physics, you're one of those guys that's always taking snap courses. What do you know about problems?

BOB: Well, stupid, I heard this one on the radio. Maybe you smart guys can answer it for me.

BILL: O.K. shoot!

JOE: Yeah. Go ahead!

BOB: Well, here it is. Let's hear you scratch your brains on this one. Which is heavier, a pound of feathers or a pound of gold?

BILL: Why, that's simple, anybody knows that gold is heavier than feathers.

BOB: Ah, I knew you'd get caught on that. Listen, dummy, I said, which is heavier a *pound* of feathers or a *pound* of gold? See, there's a *pound* of each. So . . . they weigh the same. Why don't you wake up?

JOE: Oh, I see. Sure, a pound is a pound, so, I guess that's that.

HARRY: Wait a minute, smart guy, wait a minute! I just happen to know you're wrong.

BOB: How can I be wrong? A pound is a pound, isn't it?

HARRY: Now take it easy and I'll explain it to you. First of all you must realize that you are living in a country that has a pretty screwy system of weights and measures.

JOE: What do you mean? You mean to say that our good old United States of America is screwy, or rather that it has a screwy system of weights and measures? . . . Well . . . I've heard it said that we are the most efficient nation on the face of the earth.

HARRY: Listen . . . dummy . . . you've been believing everything that the newspapers and politicians have been telling you. But did you ever take the time to look into the situation? Did you ever take the time to study the stupid, ridiculous . . . and obsolete setup that we have?

BILL: Go easy on those big words there, Harry, remember we haven't been to college yet.

HARRY: Well, then . . . to get down to your level . . . I'll say it's just plain . . . silly!

JOE: O.K. . . . O.K. . . . Now "Professor" explain the correct answer to the problem!

HARRY: Well, first off . . . the pound of feathers is the heavier.

JOE: Haw . . . haw.

BILL: I also say haw . . . haw!

HARRY: Listen . . . let me finish . . . it so happens that there are two kinds of pounds in the English system of measurements with which this country is still afflicted. Did you ever happen to hear about troy, or apothecaries' weight, and avoirdupois?

BOB: Well . . . well . . . this is confusin'! . . . but amusin' . . .

HARRY: No, it isn't amusing . . . it's tragic! Listen, one of these pounds has twelve ounces in it, while the other has sixteen. Now to get down to brass tacks—a pound of gold contains only 5,760 grains, while a pound of feathers contains 7,000 grains. Some difference, isn't it?

BILL: Well . . . I'll be darned.

JOE: Do you mean to say that we've got to put up with that kind of thing? Why a "pound" doesn't mean anything unless you know whether you're supposed to weigh something with a certain kind of pound. You always have to stop and decide what kind of "pound" to use.

HARRY: That's right.

BOB: Yeah . . . but how are you going to know which is which?

HARRY: Well . . . you can always write to the U. S. Bureau of Standards in Washington, and they'll probably send you a book of some 500 pages of fine type, and you may if you are lucky enough find what you are looking for in there. Do you know that there are probably not more than *ten* Americans who can define half of the units used in the English system?

Did you ever hear about such things as scruples, pennyweights, drams . . . short tons, long tons, and hundredweights?

JOE: Yes, yes . . . do tell us more. (ASIDE TO OTHERS) The boy is really getting warmed up, isn't he?

HARRY: Why, there's no rhyme or reason to it . . . take the units of length, they're just a hodge-podge. The foot came from the length of a king's foot, the inch . . . the thickness of a man's thumb, the yard . . . the distance from nose tip to the tip of the thumb . . . and so on . . . and so on.

BOB: So what? What difference does it make how they originated?

HARRY: Simply this . . . that there is no easy way to get from one unit to the next larger or smaller one. Take this problem that Bill has started to work—one of the dimensions that he has is "one foot and eleven inches." Change that into feet and what do you get? . . . one and 11/12 feet. You see, right away you gotta start working with fractions . . . and who likes to work with fractions?

BOB: Not me, not me . . . take 'em away . . . take 'em away. Fractions were nearly my downfall in math . . . why . . . I'll bet I've spent . . . in fact, I know I've spent 20 per cent of my school time just battling with fractions.

HARRY: Well, brother, you'd better sit down in a chair, 'cause I'm going to tell you something that may cause you to faint. Now take the metric system . . .

BILL: You take it . . . one system is enough for me.

HARRY: You're right . . . you're absolutely right . . . one system is enough for anyone. But when you decide on that one system, you want the best, don't you? . . . you want it to be the best . . . the most modern . . . the most up-to-date . . . and the most scientific system there is . . . don't you?

BILL: Sure . . . sure.

HARRY: Yes . . . and don't forget to throw the old one away . . . because it will mean just a whole lot more work for you to try and use both of them at the same time.

BOB: Say . . . that's just the mess we're in today, isn't it . . . right here in these United States? We're trying to use two systems, one a new one . . . and the other an old one which we inherited . . . and which has turned out now to be pretty obsolete too. Why . . . that makes just twice as much work for us in school without being able to accomplish anything which we couldn't accomplish with just one system!

BILL: Twice as much work, did you say . . . why it's more than that . . . it's at least four times as much work . . . because not only do you have to learn two systems, but you have to learn to change readings from one system to the other, and vice versa.

JOE: You tell 'em . . . that changing from one system to another and back and forth is a lot of work . . . Seems like we have to do that all the time in Physics.

HARRY: Well boys . . . You're coming around to my way of thinking. Listen . . . if we would adopt the metric system all the way down the line, like the scientists do, for measuring weight, length, volume and temperature, etc., we would just about throw fractions clear out the window . . . and you will all appreciate how much easier that would make the work of everybody from the youngsters down in the grades, all the way through school . . . in business . . . commerce . . . manufacturing . . . in the kitchen . . . in fact, everywhere . . . and for everybody.

JOE: How come?

HARRY: Because in the metric system all units are in multiples of ten . . . one unit is ten times larger than the next smaller, and one-tenth as big as the next larger . . . so we can do most of our work with decimals. If we want to change from one unit to the next one it is simply a matter of shifting the decimal point one way or the other depending on whether we are going to a larger or smaller one. Take this problem of Bill's here . . . if those measurements had been given in the metric system he could work the problem in less than one-tenth of the time that it will take him with the measurements as they are given there now in the English system.

BOB: Well . . . I'll say we've been gypped . . . we've been some pretty big suckers . . . and by "we," I mean all Americans who have been handed such a condition . . . why we've been made to do hours of work in school that weren't necessary at all . . . Haven't we?

BILL: That's very true!

JOE: Well, why don't we do something about it? I'd say we'd be even more stupid unless we did! Why, may I ask, hasn't somebody done something about this before . . . and saved us all this work?

HARRY: Well . . . you know how people are . . . you remember that statement in the Declaration of Independence where it says . . . All experience has shown, that mankind are more disposed to suffer, while evils are sufferable, than to right themselves by abolishing the forms to which they are accustomed.

JOE: . . . Will you say that again please . . . and say it slow . . . so everybody will get it.

HARRY: Sure . . . All experience has shown, that mankind are more disposed to suffer, while evils are sufferable, than to right themselves by abolishing the forms to which they are accustomed.

BOB: Well, if you ask me, it looks like there's some abolishing to be done around here. Looks like education could be simplified a great deal . . . doesn't it? Guess I'll have to write to my Congressman and see if I can't get him to pass a law.

BILL: Say . . . that's a good idea . . . and we'll have to do what we can to wake up the public to the situation . . . seems like they've been sleeping for a long, long time. They'll have to be educated too . . . to our present needs!

JOE: Yes . . . and think of the children just starting to school . . . wouldn't it be fine if we could save them from going through all the unnecessary work that we have had to do . . . think of our own children . . . and of our children's children for generations to come . . . unless we do something, they will be condemned to use the same senseless stupid system as we have.

HARRY: Well, boys . . . I'm glad to find that you are wide awake, now. And in behalf of the high school physics classes at Mankato High School I want to invite you to join them in their efforts to get the ball rolling on this problem—talk it up whenever you get the chance . . . sell your parents on the need . . . begin at home! If every boy and girl in this school would sell their parents on the need for this reform, we would soon have the necessary public opinion to bring about the change . . . because if you can just get people to stop long enough to think the matter through . . . you could trust to their good judgment to bring the change about in short order. (AUDIENCE APPLAUSE)

ANNOUNCER: From the stage of the Mankato High School Auditorium, *Mankato Schools on the Air,* a KYSM public service program, has presented members of the High School Physics classes in a special script written by C. J. Arnold, High School Physics Instructor. Heard in the drama were Jim Tschol as Joe, Conrad Faber as Bob, Joe Kieninger as Bill, and Jim Carlson as Harry. The production was under the direction of Miss Lucy Joyce, sponsor of the High School Radio Workshop. The members of this group would appreciate your reaction to today's program. Drop a card to them . . . addressed to this station or to the High School, letting them know whether you are for or against the changes which they propose. If you know of any club or society which would be interested in hearing more about this problem, the class will be glad to send speakers whenever possible. If you have any questions, feel free to send them in. Now here is Bob Swanson, the Mankato High School Radio Reporter with today's high school news.

STUDENT: (NEWS AS TIME PERMITS)

ANNOUNCER: Thank you, Bob Swanson. Tomorrow morning at 8:45, *Mankato Schools on the Air* will present "Wealth and Health," a visit to two important departments of every high school . . . the Victory Sales Department and the Health Department. So, join us tomorrow morning at 8:45 when you hear the sound of the school bell . . .

Sound: SCHOOLBELL RINGING . . . *under*

ANNOUNCER: It's then you hear . . . MANKATO SCHOOLS ON THE AIR.

Sound: SCHOOL BELL RINGING . . . UP FOR FILL

Girls Are for Metric, Too*

C. J. ARNOLD

THE second in a series of radio scripts for promotion of the metric system by the Director of Audio-Visual Education of the public schools of Mankato, Minnesota.

Characters: 5 girls—Beverly, Marion, Dolores, Marjorie, and Donna.

DONNA: Say, girls, did you hear that radio program awhile back that some of the boys from the high school physics class put on about the metric system?

MARJORIE: You mean that one where they said how we would be saved 20% of our school work if we discarded the English system of measurements and used the metric system for everything.

DONNA: Yeah! That's the one. What did you think of it?

DOLORES: Well, I thought they used some pretty strong language when they said our present system was screwy, and let's see —what else did they call it—oh, yes, they said that the English system was obsolete, stupid, silly, ridiculous, and a few other things.

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* Quoted by permission of C. J. Arnold.

MARION: Well, if you ask me, they weren't very tactful.

BEVERLY: Why not?

MARION: Well, because they were criticizing the ways of our elders in no uncertain terms and I'm afraid they won't like it.

BEVERLY: I know, but what they said was the truth, wasn't it?

MARION: Granted, but you know how adults are, don't you? They can be quite difficult at times. You have to know how to handle them, don't you know? You've got to be very careful you don't make them "mad" and more set in their ways than ever. You know how some of them feel—as they would say, "Well, we lived through the English system; so can you." And besides they would say, "Look how well we turned out" and "Look at what a great country we made the United States." Huh, you would think to hear them talk that we are what we are today because of our having used the English system instead of *in spite of our having used it*. Some of them are inclined to be forever wanting to preserve the "status quo" and against all progressive change.

DONNA: Yes, that seems too hard to understand at times. As we say in physics they seem to have inertia—continuing to go in the same straight line until acted upon by some outside force to change their direction of motion. We sure need some force to act on the general public today to change their direction.

MARJORIE: If we could just get the public to *think* about the problem, I think they could themselves supply a force of sufficient intelligence to make the change, don't you?

BEVERLY: Sure. When people buy new cars, they have to choose between going on with their old cars and learning to use the new ones. That's all they have to do now—choose between an old model and a new one.

MARION: Well this situation is a little different because right now as far as measurements are concerned we are using two systems at one time. Our problem is to discard the old one and apply the new one for all uses. That, *I know* would save us a lot of confusion and a lot of work.

DONNA: But some say we should stick with the English system because we started out with that one first—and keep away from this new-fangled system. They believe we should be loyal to the ways of our ancestors—they hold that what was good enough for our fathers is good enough for us now.

DOLORES: The only difficulty with that is that times change and progress is made. The metric system is a scientific system; a lot of study and work has been put in on it to make it as near an ideal system as it is possible to make it.

MARION: It seems to have been just what the scientists wanted because it is the system used in practically all scientific work.

MARJORIE: Not only is it used by the scientists, but most all of the new industries have adopted it, and many of the old industries are trying to put it into use too. Radio, for example, is all metric. This station ——— broadcasts on ——— kilocycles, and its wave length is given in meters. Motion picture film is rated as 8, 16, or 35 millimeters. We buy our electricity in kilowatts instead of horse power.

BEVERLY: And girls, did you know that in most hospitals they weigh newborn babies in the metric system, but announce the weight to the parents in the old units to avoid misunderstanding and confusion.

DONNA: Yes, and hospital patients are as a general thing fed by the metric system. They are supposed to have so many grams of this and so many grams of that—and so many cc.'s of various liquids. Of course, as you well know, whenever the doctor gives an inoculation, it's always so many cc.'s of vaccine, or whatever it is that they shoot into you.

MARJORIE: And did you know that when they take X-rays, all the measurements are made in metric, usually centimeters?

BEVERLY: The fact is that the metric system is crowding in all around us, so that it is just a question of how long it will take before it replaces the English system for every use. As the saying goes, "Eventually, why not now?"

DOLORES: A change always takes time, so maybe we should say, "Eventually, why not pretty soon?"

MARJORIE: Seems to me an effort should be made to speed things up, particularly the discarding or outlawing of the old English system.

MARION: Gee, I'll sure be glad when we use the metric system in our kitchens. Can you imagine anything that will contribute more to success in baking than having a scientific system of measurements. Imagine how much better it will be to measure in cc.'s instead of spoonfuls and cupfuls. You know how that works out Beverly, because you have done it.

BEVERLY: Yes, I've worked out quite a number of metric recipes, and what's more I've tried them out on my family—and they're still very much alive. You know, I think it's going to be very nice for us girls when we can get rid of that double standard English system—with its two kinds of pints—the dry pint and the liquid pint. It's all very confusing because the dry pint is bigger than the liquid pint and lots of times it's hard to tell which one it is supposed to be. The liquid pint is only about 47 cc.'s, while the dry pint is around 55 cc.'s. That is quite a difference.

DOLORES: It's the same way with bushels—the farmers sure have a hard time keeping their bushels straight, usually have to carry a little book around with them. One kind of bushel has 32 pounds, another 48 and so on and on, to make about a hundred different sized bushels. And it's pretty much the same for the other English units.

MARION: Yes, it's a bad situation—but getting back to the kitchen. Everyone has accepted the metric system when it comes to dieting. We have figured out how many calories there are in all the different foods—so we need to get used to weighing food portions in grams and computing the calories per gram.

And when it comes to other essential ingredients in our diet such as minerals, we find them weighed in the smaller metric units such as the milligram.

MARJORIE: But I think that one of the nicest things will be that when we adopt the metric system in our kitchens we will do away with fractions—no more 1/2 teaspoons—or 1/4 cups—or 1/8—or some similar measurement. Instead it will be 5, 10, 15, 20 or so cc.'s, just as they do it in the research laboratories.

BEVERLY: It seems to me that we girls should use the metric system so that we will be better able to understand and visualize scientific magazine articles about food studies. Then we would be speaking the same language as the technicians use in their laboratories. We would be able to visualize the amounts referred to, and so we would be better able to do our all important job of preparing the food for our families. We've got to prepare balanced meals. You know, I don't like it the way it is now. It seems to me it is a reflection on the intelligence of the housewife. The experiments in food nutrition are all worked with the metric system, but when the results are published they are all changed to the old system because they are afraid we couldn't understand them. How dumb do they think we are anyway? We studied the metric system in school and what's more we like it—'cause it makes good sense. Why look at some of the silly and unscientific things they publish for our supposed benefit. Here for example is a sample—"One slice of bread contains 100 calories." How big is a slice of bread, I ask you? Why it can be any size. Why don't they say exactly how much bread and be scientific about it?

MARJORIE: Yes, that's just like some of the recipes, I've seen, where they say, "Take the juice from one orange." There certainly is no exactness about that. It's hard to find oranges of the same size and even if you did some would have more juice than others. Why not say, "take 10 cc.'s of orange juice"? Let's do away with such unexact measurements as, "one egg," or "one potato" or "one tomato." Let's specify the exact amount and say for example, "5 grams of potato." When housewives start using exact measurements like that they can expect to get uniform results in baking, just as the scientists do, and just as they do in the large bakeries. They know that if they always use the same proportions in making a cake they will always get the same results.

MARION: You know, we should follow the example of the scientists, because our work in the kitchen is becoming an exact science too. When they started they were using exactly the same measurements that we use in the kitchen now—teaspoons, cups, and what have you. I move that we throw the old system out and put the metric system in for everything from "soup to nuts" so to speak.

DONNA: Well, I do too, but what can we do to speed the day along?

DOLORES: We will have to do our part in educating the public so as to build a strong public opinion to help bring the necessary legislation about. In fact, I've prepared a statement which I would like to read into the "records" as it were—

DONNA: O.K. Let's have it.

DOLORES: When the women of America are convinced of their responsibility in bringing about the change from the old obsolete units of measurement to the more modern and scientific ones, there are several avenues of action open to her:

FIRST. She can talk the matter up with her neighbors, in her clubs and other organizations to which she belongs—always insisting on action. She should have her organizations go on record for such a change.

SECOND. She can exert great pressure because she spends the greater part of the family income—by asking for things in metric units—she can express a desire that things be offered for sale in these units. If enough women do this, the enterprising merchant and manufacturer will quickly respond to satisfy her requests. Competition will cause him to label his goods, at first, in both units as some do already. Some will begin to feature recipes in the metric system.

Eventually, the old system will disappear. If the women of America said the word the change will come in short order.

THIRD. She can write to her legislative representatives and let them know her wishes. Laws will have to be passed, and they will be passed when enough women ask for them.

FOURTH. She can insist that the Federal Government set an example for the rest of the nation. Since the metric system has already been made legal by Congress she can ask her governmental representatives to insist that all government business and transactions of all kinds, wherever possible, be in the metric system.

BEVERLY: I agree with you 100%.

MARION: I believe that those who come after us will appreciate our efforts to give them a modern and scientific system of measurement just as they should appreciate the efforts of Thomas Jefferson in giving us a similar system for money.

DOLORES: And I believe that they will appreciate just as much the removal of the present English units in common usage as we should appreciate the fact that we don't have to labor under the cumbersome English system of money with its pounds, shillings, pence, etc. Don't you?

BEVERLY: Yes, I believe you are absolutely right. And I think it is better to have one good simple system like the metric and use it for everything than to have to learn two different systems. To use two systems is bound to cause unnecessary confusion in changing units from one system to the other. This is foolish especially when one of the systems is already obsolete from the international point of view. Did you know that 75 per cent of the entire world's population is now using the metric system and that 55 out of the 57 so-called civilized nations in the world have made its use mandatory? *I'm ashamed* that we are *one of the two backward nations* still hanging on to our old ways simply because we haven't enough individual initiative and enterprise to cast off our old methods and take full advantage of benefits to be derived from the complete use of the newer scientific method.

MARION: Bravo!

MARJORIE: What do you say we go to work on it!

DONNA: And see if we can't help in bringing about the change.

DOLORES: You can count on me.

BEVERLY: I'm all for it, too.

Clubs

The Metric System*

ELEONORE F. HAHN

The adoption of the Metric System by the United States of America would greatly reduce labor in trades because of the thorough decimal quality of the system, and would facilitate teaching of mathematics and applied sciences in school.

Charles W. Eliot
Late President Emeritus
Harvard University

DISADVANTAGES OF THE PRESENT SYSTEM

WE KNOW "there is no royal road to learning," but we can find a method which will relieve the burden and ease the path, and that is to "turn the tables." Let the simple decimal system, the metric system, be removed from its place in the background, and the old heterogeneous mixture be relegated to oblivion.

Educators state that one year in the arithmetic school-life of every American child could be saved if the metric system replaced our present complicated tables of measurement, arithmetics in metric countries being one-half as large as ours. Since there are over 25,000,000 public school children in our country, the saving in time and money would be considerable. Even more important is the relief granted to the children from the dreary drudgery of committing to memory illogical and unconnected terms. In addition to the great variety of units, there are numerous meaningless figures which the child-mind must acquire and retain: for example, 5,760 grains in a pound troy or apothecaries' weight; 7,000 grains in a pound avoirdupois; 5,280 feet in a mile; 231 cubic inches in a gallon; 2,150 cubic inches in a bushel; 1,728 cubic inches in a cubic foot. These cumbrous figures must be used in different calculations. How easy to make an error in computation even if the mind held the different figures!

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* This article was circulated in mimeographed form among clubwomen in the United States by the General Federation of Women's Clubs in 1944.

SIMPLICITY OF THE METRIC SYSTEM

Our English system has a vast number of units; the metric system has but three—the meter for length, the liter for capacity, and the gram for weight. While our system involves the use of unwieldy common fractions, the metric calculations are all decimal, the tables planned like our currency; the main unit has subdivisions of thousandths and hundredths, known by the Latin prefixes *mill-* and *cent-* (already familiar to us through our currency). While there is no relation between our units of length, capacity, and weight—for example, the yard, the quart, the pound—the metric units of capacity and weight are formed from the measures of length: the meter, which is 10 per cent longer than a yard, is the standard unit from which all others are derived; the liter, which replaces the dry and liquid quarts, fills a container measuring 1,000 cubic centimeters; and the gram is the weight of 1 milliliter of water.

Six statements comprise the whole system. They are as follows:

LENGTH

10 millimeters (mm) = 1 centimeter (cm)
100 centimeters (cm) = 1 meter (m)
1,000 meters (m) = 1 kilometer (km)

CAPACITY

1,000 milliliters (ml) = 1 liter (l)

WEIGHT

1,000 grams (g) = 1 kilogram (kg)
1,000 kilograms (kg) = 1 metric ton (t)

THE METRIC SYSTEM IN THE UNITED STATES

In 1792, the United States discarded the cumbrous English currency of irregularly divided pounds, shillings, and pence, and adopted the metric decimal dollar; but the legislators unfortunately failed to adopt the three metric units of weights and measures, meter, liter, and gram. In 1866, Congress legalized the metric system, but missed the opportunity for complete simplification by not making it the exclusive standard.

THE METRIC SYSTEM IN USE

The application of the decimal to weights and measures originated in 1783 with the British inventor, James Watt, who thought out and suggested the decimal system as the way out of the intolerable confusion caused by the lack of a world language for the expression of quantity.

Fifty-five nations, one after the other, discarded their local measures and adopted the metric system. Of all the civilized world only the two great English-speaking nations cling to outgrown, unwieldy methods. Uncle Sam and Cousin John Bull must realize that certain important units of measure used in the United States and Great Britain which bear the same name are not actually the same, thereby causing confusion and loss of efficiency. The change to the decimal system of weights and measures in place of the customary irregular and complicated so-called English units would simplify everyday dealings, both commercial and other transactions. The calculations made essential by the transfer of one system of weights and measures to the other in importing and exporting goods cause a great loss both of time and of money.

The metric system is now used in the United States by the U. S. Coast and Geodetic Survey in basic triangulation survey of the country and by the army in design and armament; exclusively in electrical measurements; generally in laboratory and other scientific practice; by many physicians in prescribing medicines, and hence by pharmacists; and in international athletic events.

A recent survey of metric usage in the United States shows that educators are nine to one, and manufacturers are two to one, in favor of metric usage.

The manufacturers who are opposed to the adoption of metric measurements fear the initial expense in converting or replacing measuring apparatus, tools, and machinery in general; but experience has shown that the change can be gradual and pays for itself in improved trade relations. Those factories that have made the change testify that the expense was outbalanced almost immediately by the savings incident to the use in commerce of the easily computed decimal system. World War I proved the facility with which the United States could change to metric measurements. In World War II the manufacturers have had to make new machines and new machine tools to turn out the new products required by the war. Here was a great opportunity to switch from feet and inches to millimeters. As a matter of fact, they did make some switchovers, to which they paid little attention under pressure of war. Right at this time many plants are producing 37-millimeter cannon, 75-millimeter field pieces, 90-millimeter guns, 105-millimeter howitzers, and 155-millimeter "long Toms"; and they make ammunition to fit. This requires machines and machine tools built to metric measurements.

The full adoption of the metric system by the United States would be of great benefit to this country in postwar reconstruction; in promoting commercial relations, particularly with the countries of South America, Continental Europe, and Asia; and in providing for the operations of world trade an international language.

Resolutions in Favor of the Metric System

THE GENERAL FEDERATION
OF WOMEN'S CLUBS

AT THE Annual Convention of the General Federation of Women's Clubs held April 25-28, 1944, in St. Louis, the following resolution was introduced and adopted unanimously by the delegates. This organization represents 16,500 clubs and 2,500,000 individual members.

Whereas, the irregular, numerous, unwieldy, and complicated units of weights and measures used in the United States and Great Britain are a hindrance to the teaching of arithmetic, everyday commercial transactions, and world trade, and

Whereas, the metric system of weights and measures has only three units; meter, liter, and gram, interrelated and decimally divided like our dollar, and

Whereas, the metric system is now used in the United States in science, some factories, jewelry and optical industries, all electrical and radio measurements, athletic events, some hospitals and government departments, and especially at present in the manufacture of ammunition, and

Whereas, the Council on Pharmacy and Chemistry of the American Medical Association has recently decided that henceforth it will use only the metric system, and

Whereas, the gradual introduction of the metric system in this country (exactly as it has been introduced in 55 other countries) is feasible, and

Whereas, the full adoption of the metric system by the United States would be of great benefit to this country in post-war reconstruction, in promoting international commercial relations, particularly with the countries of Latin America, Continental Europe and Asia, therefore be it

Resolved, that the General Federation of Women's Clubs in Convention assembled, April, 1944, endorses legislation in Congress for the nation-wide adoption of the metric system of weights and measures.

The foregoing resolution was drawn up and presented by

Eleonore F. Hahn (Mrs. Otto Hahn)
Member of the Board of Directors

THE ROTARY CLUB
MANKATO, MINNESOTA

Metric Resolution: The Rotary Club of Mankato, Minnesota, having discussed the merits of the metric system of measurements and believing the replacement of the English system by the metric system to be highly desirable in order to bring about a simplification in Education urges the consideration of the adoption of the metric system by all Rotary Clubs in the U. S.:

WHEREAS, a trend in the U. S. is indicated for the replacement of our old units of measurement with the more modern and scientific metric units as shown by their use in most of the new industries, such as electrical, radio, motion pictures, pharmaceutical houses, jewelers, and optical goods manufacturers; and

WHEREAS, the metric system is used for practically all scientific work, and it might be desirable for the general public to use the same measurements in order that they might become more scientific and be better able to assimilate easily and readily and understand new scientific facts and research; and

WHEREAS, the full use of the metric system, which is a decimal system, will eliminate for all practical purposes cumbersome and unwieldy "fractions" in mathematical computations, thus greatly simplifying Education as well as Business and Commercial transactions and Living in general; and

WHEREAS, our school children are at present handicapped by our dual system of measurements which necessitates their learning two separate systems of measurements as well as the equivalents necessary for converting units of each system into the other thus making this part of their education much more difficult than it need be; and

WHEREAS, in a world where 75% of its total population and 55 of its 57 civilized countries have already converted to metric usage, with no probability of any of these countries adopting the English system; therefore be it

Resolved, that the Rotary Club of Mankato urge congressional action at the earliest possible time to bring about the replacement of the obsolete English system of measurements with the far more simple and easy to learn metric system; and be it further

Resolved, that this organization invite the consideration by all Rotary clubs in the U. S. of this resolution and urge their adoption of this or similar resolutions.

Drawn up and presented by C. J. Arnold. Reviewed by its Board of Directors. Adopted.

John F. Meagher
President

June 13, 1946

THE KIWANIS CLUB
MANKATO, MINNESOTA

METRIC RESOLUTION. At a meeting of the Board of Directors of the Mankato Kiwanis Club held at Mankato on June 11, 1946, the following resolution was presented and unanimously adopted:

WHEREAS, the advantages of the metric system, well known to scientists and mathematicians, would be in harmony with the simplification procedures which will be a part of the post-war reconstruction program, and

WHEREAS, the metric system reduces all necessary computation in measurement to the operations of whole numbers, thereby greatly simplifying the learning of arithmetic by children, and

WHEREAS, there has been a long steady trend in metric adoption by 55 of the 57 countries of the world, and

WHEREAS, there is no probability among the nations now on a metric basis of going back to the English system, thus necessitating the use of two systems with the accompanying inconvenient and time-consuming inter-conversions instead of one simple system, and

WHEREAS, the close of this war will furnish an opportunity never before presented, when customs and habits have been torn loose from their ruts,

Therefore Be It Resolved that the Kiwanis Club of Mankato go on record as favoring some form of legislation for immediate metric usage in those lines most feasible for metric adoption.

Drawn up and presented by
A. P. Krost
Secretary

THE LIONS CLUB
NEW CANAAN, CONNECTICUT

THE Lions Club of New Canaan, Connecticut, having studied the merits of the Metric System and believe it to be of great benefit to our nation, the following resolution was therefore unanimously adopted with the recommendation that every effort be put forth toward its adoption by the Congress of the United States of America.

RESOLUTION

WHEREAS: All of the nations of the world except Great Britain and the United States of America now use the Metric System, which is not only far more simple and easier to learn but eliminates fractions and puzzling measurements, and

WHEREAS: Some of the possessions of the United States do now use the Metric System with success, and

WHEREAS: Most of the men in the armed forces have become familiar with and are now using the Metric System, and

WHEREAS: Most of the machinery now used for war work will of necessity have to be changed for post war, and

WHEREAS: In dealing with other nations with which we hope to trade, they will demand of us the same measurements that they now use, and

WHEREAS: Many manufacturing plants already use the Metric System, likewise, pharmaceutical houses, jewelers and optical-goods manufacturers, and

WHEREAS: Many of the noted industrialists, world tradesmen and educators are ardent supporters of the Metric System, therefore be it

Resolved: That the Lions Club of New Canaan, Connecticut, recommends the adoption of the Metric System to be used in the United States of America, and be it further

Resolved: That every effort be put forth toward the establishment of the Metric System by Congress.

Wilbur J. Dixon
International Counsellor
W. R. J. Planten
Committee

May, 1944

CHANGE TO METRIC AND OUR CHILDREN WILL RISE UP AND CALL US BLESSED

The Lions Club of New Canaan, Connecticut are pleased to submit the following in conjunction with its resolution regarding the metric system.

We Americans consider ourselves to be quite as progressive and efficient as any nation on earth. We are impatient with outmoded methods and are continually striving to outdo the other fellow. We have streamlined our trains, we have built airplanes to carry great loads, yet our airplanes of today will be obsolete tomorrow, and even now we are building rockets with the hope that we will soon be making contact with the moon.

How we would resent an accusation that we were in any way one of the most backward nations of the earth, and in this one thing we are, that of our system of weights and measures. All of the world with the exception of ourselves and Great Britain have long since gone metric, and England is now in a state of transition, which will mean that soon we will stand alone with the same outworn system that we used in the days of the tallow candle and the flintlock musket.

We have decided that metrics shall be used in Hawaii, Puerto Rico and the Philippines, and if we think it should be used there why should we not use it here at home? We in the continental United States are indeed a divided nation in that many of our leading industries have already adopted the metric system in the interest of simplicity, accuracy and true economy. In a single year they have saved ten times the cost of the new measuring devices, but the rest of us, on our farms, in our business, in our offices and schools must wrestle with troy and avoirdupois, grains, scruples and pennyweight, the three kinds of tons, the great number of kinds of bushels, and all kinds of fractions and complex problems when it could be made as simple and easy as our system of money.

We can only imagine the impatient exasperation of the other nations with whom we attempt to do business when they attempt to comprehend our complex and unfamiliar standards. How often now, and how much more in the future will they prefer to trade with the other countries whose standards of weight and measure are like their own. We can not afford to lose the markets of the world just because of our unwillingness to get in step with all of the nations of the world except Great Britain.

During the war we accomplished the impossible to the astonishment of the world. Under the spur of necessity we devised new methods and acquired new skills.

Now that the war is over we are converting our whole economy to the art of peace. Shall we, who in war made so great an advancement, confess ourselves unwilling to bring into our schools and business that short and accurate method of metric which will cause our future generation to rise up and call us blessed?

Let us not put off until tomorrow what can and should be done today but put all of our energy into making this world a little better because we have lived in it. Let us make history now.

Wilbur J. Dixon
Chairman of Activities Committee
and Treasurer

4. *Toward Wider Use*

METHODS OF MAKING THE CHANGE
TO THE METRIC SYSTEM BOTH IN
GENERAL USE AND IN EDUCATION

General

The Metric System: An Anglo-American Opportunity

HARRY ALLCOCK

THE intensive development of aerial transport and wireless communication is rapidly bringing the peoples of the world into closer contact, and it is accordingly not surprising that various attempts are being made to secure the adoption of a universal auxiliary language for common use in international business. It will be recalled that Roosevelt and Churchill suggested what was known as Basic English for that purpose, but, as there are so many other proposals with the same objective, it must be admitted that at best some years must elapse before general agreement can be reached and applied.

Meanwhile the establishment of a single system of uniform units of weights and measures for the common use of the producers, distributors, and consumers of all products in all countries is an ideal which, owing to the progress made in other countries, is now within the range of practical politics. It may not be generally realized that, while there are scores of languages of description, there are now, in effect, only two languages of quantity in international commercial use, namely, the British imperial system (including certain American modifications) and the international metric system of weights and measures.

A comparison of the merits and claims of these two systems indicates that the world has already made its choice and justifies the confident belief that the metric system is destined to become the sole system. In support of that view it may be noted that the International Chamber of Commerce has officially recommended "that all systems of weights and measures, other than the metric system, be abandoned," and, similarly, that the International Business Conference at Rye, New York, attended by representatives of fifty-two nations, resolved: "There should be adopted for use in international trade a single system of weights and measures, preferably the metric system."

Since its introduction by France at the end of the eighteenth century, more than fifty other countries have established the metric as their sole legal system of weights and measures. The accompanying list is arranged in order of the twenty-year periods during which the several parliaments adopted legislation making compulsory the use of the metric system in their territories.

Period	*Country*
Before 1820	France
1820-1840	Belgium, Luxemburg, Holland
1840-1860	Spain, Colombia, Panama
1860-1880	Mexico, Portugal, Uruguay, Italy, Brazil, Chile, Ecuador, Peru, Germany, Serbia, Austria, Hungary, Czechoslovakia, Switzerland
1880-1900	Norway, Argentina, Yugoslavia, Rumania, Costa Rica, Salvador, Sweden, Bulgaria, Egypt (partial), Finland, Bolivia, Nicaragua, Guatemala, Tunisia, Honduras, Haiti, Paraguay
1900-1920	Philippines, Denmark, Iceland, Venezuela, Turkey
Since 1920	Poland, Malta, Greece, China (partial), Russia, Japan, Morocco, Persia, Afghanistan

The colonies and dependencies of the countries listed have also naturally followed the metric flag. The decisions of the governments of Russia, Japan, and China are especially noteworthy in that they represent a large portion of the world's population. Critics of the metric system used to say that it could never claim to be an international system so long as the Far East held aloof. That reservation is no longer valid.

The further claims of the metric system include the following:

1. In addition to being required by law in the above countries, its use is now legally permitted in all other countries throughout the commercial world.

2. Every country, when discarding its own national system, has selected the metric system; and no country, having once adopted it, has ever abandoned it.

SCIENCE AND INDUSTRY

3. The *Report on the Position of Natural Science in the Educational System of Great Britain* (Cmd. 9011) states: "The present chaos of imperial weights and measures causes waste of time and confusion of thought, and that there are strong educational reasons for the adoption of the metric system."

4. Scientists throughout the world, including those resident in countries where there is no legal compulsion to employ the metric system, have already adopted it as the basis of their work. The desired intimacy of contact between scientists and industrialists would be promoted by their use of a common language.

NEW INDUSTRIES

5. The newer industries in all countries, such as wireless telegraphy and telephony, broadcasting, and manufacturing of aircraft, scientific instruments, parts of motor cars, lenses, and so on, express their principal dimensions in metric terms.

Manufacturers contemplating the establishment of further new industries or of new standards in old industries should be encouraged to base their new designs on the metric system at the outset.

EXISTING PLANT

6. There would be no need to scrap existing plant and equipment used in production if the metric system was adopted. The description for sale in metric terms of goods made to non-metric dimensions is already the common practice of manufacturers whose products are exported to "metric" countries. Metric equivalents expressed even so approximately as to the nearest whole millimeter—thus dispensing entirely with the decimal point—could not differ from the original imperial dimensions by more than one fiftieth part of an inch, which is sufficiently near for most

classes of goods. For dimensions of closer precision, for example, for running machinery, the metric equivalent to the nearest hundredth part of a millimeter—involving two figures after the decimal point—represents even greater refinement of accuracy than is obtainable in modern factories where such work is now commonly measured in thousandths of an inch, requiring the use of three figures after the decimal point. (Purists sometimes attempt to increase the apparent difficulty of stating metric equivalents of inch dimensions by employing six figures after the decimal point, notwithstanding the fact that the last four of those figures have no practical significance and may therefore be ignored.) [See pages 233-259.]

ANGLO-AMERICAN OPPORTUNITY

7. A study of the above list of "metric" countries reveals that it now lies within the power of the governments of the United States of America and of the United Kingdom to establish the desired uniformity of use throughout the entire world. The expression *United Kingdom* is deliberately used here instead of *British Empire* because the attitude of the British Dominions was clearly stated in the Dominions Royal Commission Report of 1917 in the following words: "There is clearly in the Dominions a considerable body of opinion in favour of the change [to the metric system]. So far, however, all efforts to induce the community of the Mother Country to agree to the change have proved unavailing."

8. The use of the metric system is already legalized in both the United States of America and the British Commonwealth of Nations, and the time has arrived for them to advance from passive permission to active encouragement, leading ultimately to legal compulsion. If neither the American Government nor the British Government desires to take the initiative, the possibility of their joint action should be mutually examined. If joint action cannot be arranged, the lead of either would be followed by the other to avoid its isolation from the rest of the world.

9. It is no longer a case of the imperial system *versus* the metric system, but rather of the use of one system only—the metric sys-

tem—as against the continued use of two conflicting systems and the consequent waste of time and risk of error in making ever-increasing numbers of conversions to and from the metric system. No trader in any nation (whether "metric" or otherwise) can now escape the obligation to use the metric system more and more year by year in order to gain and retain the good will of his actual and potential customers in "metric" countries. This being the case, steps should be taken to hasten the abandonment of all other systems in order to shorten the period in which mixed systems must still be used to the progressively growing disadvantage of all concerned. An announcement by the American and British governments—either jointly or separately—that their policy is ultimately to establish the use of the metric system for all purposes would do much to shorten the transition period.

10. This urgent reform ought not to be set aside on the grounds that there is insufficient public demand for it. There never can be a popular demand for such a technical objective, but government inaction cannot be justified on that account. Weights and measures may be regarded as tools of trade which the government —and the government alone—can provide. The American and British trading communities are entitled to demand that these government-provided "tools" are at least as efficient as those employed by their foreign competitors and customers. Appropriate action at this time of reconversion from war to peace would be interpreted as a significant gesture that our governments are prepared to play their part in improving the efficiency of all our trading operatives at home as well as abroad.

THE TRANSITION PERIOD

The following steps might usefully be taken by the governments of America and the British Commonwealth of Nations to facilitate the gradual abandonment of outdated and local systems in favor of the international metric system:

1. Proclaim that, as of a given date, the already legalized metric system shall be the sole legal system in the sale of goods and services, without necessarily altering their existing dimensions.
2. Specify the requirements of government departments in

metric terms and encourage other large buyers to adopt similar procedure.

3. Encourage manufacturers and merchants to express all dimensions in metric terms in advertisements, catalogues, price lists, and other trade literature.

4. Delete redundant denominations of non-metric weights and measures so as to facilitate the ultimate changeover to metric units. For example:

a. Apothecaries' weights. Abolish the entire table of these weights, which are falling into disuse, and so eliminate the risk of confusing grains and grams in medical prescriptions. This step has already been taken in South Africa, and a similar trend is now being followed by the American Medical Association,

b. Troy weights. Abolish the entire table of these weights and employ only metric weights. In the year 1913, on the urgent representation of the wholesale jewelers, the British Deputy Warden of Standards secured the issue of an order in Council making all the then existing varieties of carat weights illegal and proclaiming a new standard carat of 200 milligrams.

c. Avoirdupois weights. Abolish the stone, quarter, hundredweight, and ton, expressing their weights in pounds only. At present the stone may be regarded as either 8 or 14 pounds; the "hundred" weight is 112 pounds; and the world ton may be interpreted as 2,240, 2,000, or 2,204 pounds, or 40 cubic feet, according as the long ton, short ton, metric ton, or shipping ton is indicated. In South Africa, railway freight charges are quoted in pence per 100 pounds. Compare this with tons, hundredweights, quarters, and pounds at pounds, shillings, and pence per ton or other unit!

d. Measures of length. Abolish the fathom, pole, chain, and furlong, expressing their lengths in yards only, ready for the direct conversion from yards to meters after these redundant denominations have been eliminated.

e. Measure of capacity. Abolish the gill and bushel and establish a new gallon of 4 liters or metric quarts. The existing imperial and American gallons differ from each other by about 20 per cent, and the proposed new metric gallon would represent an intermediate volume larger than the American gallon and smaller than the imperial gallon.

Agnew Suggests Renewed Consideration of Metric System for America*

IN A LETTER of May 18 to the members of the [American] Standards Association, the secretary, P. G. Agnew, outlined the present situation on the use of metric units and suggested that a council discussion of the subject might be constructive. His letter, giving past history and possible moves by American industry, follows:

"1. During the last few years the ASA staff has been approached more and more frequently regarding the use of metric units.

"2. Recently the Electric Bond and Share Company has proposed that ASA take up with the United Nations Standards Coordinating Committee the question of what can be done to mitigate the difficulties which arise from the use of the two systems of weights and measures. The Electric Bond and Share Company has built power houses in metric countries aggregating [illegible]00,000 kilowatts, and so has continually faced these difficulties.

"3. The Advisory Committee on UNSCC Work has considered this request and has decided that it would be well to have a discussion of the whole question in the Standards Council.

"4. The Committee also asked me to prepare the ground for the discussion by the circulation of this memorandum.

"5. For many years the metric question was the subject of acute controversy in this country. The controversy threw much heat but very little light on the subject. Practically all of the leaders on both sides of the controversy have now passed from the scene.

"6. Any attempt either to force the adoption of the metric system by mandatory legislation, or to force the exclusive use of the English units would only end in fruitless controversy.

"7. Yet the question is of great and growing importance. It is of special importance to our foreign trade.

"8. The use of the metric system is steadily growing in this country. ASA committees use it slightly more year by year. While it has been edging in chiefly from the scientific side, some industries have used it much more during the war. Among these are the aircraft, electric wire and cable, and the chemical industries. The U. S. Pharmacopoeia has dropped the apothecaries' units and is using the metric units only.

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* Reprinted from the August, 1945, issue of *Refrigerator Engineering* by permission of *Refrigerator Engineering* and of P. G. Agnew.

"9. Furthermore, in modern mass production methods the unit of length has become less and less important in comparison with the actual size of the product. The scale and calipers are little used by the modern inspector who relies on "go" and "no-go" gages. Furthermore, with the advance of manufacturing methods and the use of tolerances and allowances, even inches, halves, quarters, etc., are becoming less and less important. This is especially true as more and more use is being made of the technique of providing for the wear of tools and gages, and the consequent use of unilateral tolerances.

"10. It seems extremely probable that regardless of what system is eventually adopted we shall have to live with both English and metric units for at least a generation. Would it, therefore, be the constructive thing for industry to adopt a policy of studying the whole question from the point of view of minimizing the difficulties of having to live with both systems for years?

"11. Throughout all of the controversies of the past no thorough study has been made of what could be done to alleviate the confusion which results from the use of two systems or to determine precisely what difficulties would be encountered if there was a progressive change to metric units.

"12. There is reason to believe that the old controversies have died down sufficiently so that a constructive job could be done. Possible action might be taken along the following lines:

(*a*) A slight step has already been taken in all the industrial countries in agreeing upon the conversion ratio of 25.4 mm to the inch.

(*b*) Different countries could agree to the proposal that has been made by the various national laboratories to go over to the wave length basis for the legal definition of the inch and the millimeter.

(*c*) Each country might well give consideration to recognizing both the pound and the kilogram in setting impost duties. This could readily be done in such a way as to facilitate trade between "pound" countries and "kilogram" countries.

(*d*) National and international agreements could be made for industry to take a leaf out of experience in scientific work by using fewer metric units, e.g., concentrate on use of the micron, millimeter, meter, kilometer; microgram, milligram, gram, kilogram, metric ton, etc., etc. Some small steps could doubtless be taken in this direction with the English units.

(*e*) Go further in the use of decimals and in the elimination of fractions. There is a strong tendency in this country in this direction, e.g., vulgar fractions are being eliminated in drawings for airplane engines, most dimensions being given in decimals of an inch.

(*f*) The tendency to mark measuring instruments in both systems could be encouraged.

(*g*) Improvement in educational methods in primary, technical and engineering schools.

"13. Another basic approach would be for each one of the major industries to make a thoroughgoing study of its particular problems, and if possible determine a policy *toward* the metric system which it might follow for the next fifteen or twenty years.

"14. One industry might decide that it would have to stick strictly to the inch and the pound in all of its operations. Another industry might decide definitely toward the exclusive use of the metric units. Still another industry might decide to move in the direction of a divided use as between domestic and export—or might stick by the inch for certain purposes, such as screw threads, but go over to the kilogram for weights.

"15. I believe that there is much to gain by a thorough discussion of the whole question at this time."

Simplified Practice and Standardization

THEO. A. SERAPHIN

SIMPLIFIED PRACTICE is simply the application or use of common sense in an unselfish effort to do things most economically and practically and to accomplish the greatest good with the full use of standardization for the general welfare of the public. It will greatly reduce waste of material, time, and money; it will increase production and lower our cost of living; and it can greatly help in stabilizing our moral and economic structure.

There is an almost unlimited field for simplified practice, for it is applicable to every phase of our life, including all branches of our government, national, state, and local, from the highest to the lowest; every type of business, from manufacturing to farming; every profession, including medicine, law, dentistry, and so on; every branch of engineering; building; contracting; banking; the activities of trust companies; labor; housekeeping; education; and even religion. The potential monetary benefits alone, through its general application, can be measured only in billions of dollars per year.

Simplified practice and standardization were first introduced into our American life back in 1792 when our decimal monetary system was set up. Practically nothing further was done by the government until shortly after World War I, when a special department was created in the Bureau of Standards, called the Division of Simplified Practice. This is credited with accomplishing a vast amount of good; yet its achievements are negligible when compared to the vast field to be covered, for its activity is limited to the means provided by the government for this purpose.

The creation of departments of weights and measures throughout the various states and cities in the past quarter-century or more is only one phase of simplified practice and standardization. The activities of these departments are chiefly confined to assuring honest weight and measure to the public in the purchase of food, fuel, and other commodities and to regulating the manufacture of honest weighing and measuring devices. This activity also protects the honest merchant from unfair competition by dishonest merchants. The savings to the purchasing public from this activity alone amounts to well over $100,000,000 each year. In 1914, when the Philadelphia Department of Weights and Measures was created, a survey showed that in that city alone the yearly loss arising from dishonest merchants and faulty weighing and measuring devices was estimated at $50,000,000.

The efficiency of the various departments of weights and measures throughout the United States could be greatly increased if this country would use the simplified metric system of weights and measures in place of the antiquated English system. The use of the metric system would not only save time and money for all but also shorten by at least a year the public school education of our children.

It was in 1792 that our forefathers undertook to simplify both our confused system of coinage and our system of weights and measures. They adopted a decimal system for our money, based on the dollar as the unit of standard; but they failed to adopt the same system for weights and measures, and to this day this shortsightedness has been frequently condemned.

By an act of Congress in 1866, the use of the metric system was made legal but not compulsory. For a number of years efforts have been made by private groups to help bring about its final adoption, but there have always been some groups in opposition, some actuated by selfish interests and using paid agents to oppose adoption efforts.

Our present system of coinage is an example of simplification in measurement. It is based strictly upon the decimal system of ten. It combines simplification and practicability in the highest degree, in that ten or a multiple of ten of one denomination equals one unit of another. It is so simple that it is one of the first things in arithmetic with which little children become thoroughly familiar. The same thing is possible with the metric system of weights and measures. Today both the old system and the metric system are used throughout the United States by nearly all government agencies and private industries, both large and small. There remains only one element of our nation to accept or use the metric system in order to make its use complete—the purchasing public, including both the housewife and the general storekeeper.

I will venture to say that not more than one-half of 1 per cent of all the people in this country become thoroughly familiar with our present system of weights and measures during their entire lifetime, and I know that not one person in our entire nation would consider for a moment the exchanging of our metric system of coinage for that of England or any other nation whose coinage system resembles that of our old weights and measures.

I will say further that the public never inquires how many cents there are in a dime or how many dimes in a dollar, but inquiries are frequently made as to the number of

Cubic inches in a gallon (231)
Fluid ounces in a pint (16)
Cubic feet in a cord of wood (128)
Cubic inches in a bushel (2,150.42)
Square feet in an acre (43,560)
Cubic feet in a perch of stone (24.75)

Then one may ask, what is a firkin (9 gallons), a tierce (42 gallons), a token (10 1/2 quires or 252 sheets), and various other units of weights and measures, such as pennyweights, scruples, drams, and what not; and these inquiries are most frequently made by quite intellectual persons. We also have two kinds of quarts and pints, dry and wet; two kinds of tons, short and long (some are at times extra-short); two kinds of pounds, one having 5,760 grains and the other 7,000 grains; two kinds of bushels, heaped and struck. Then again we have 3 barleycorns, 1 inch; 2 1/4 inches, 1 nail; 4 nails, 1 quarter; 3 inches, 1 palm; 4 inches, 1 hand; 36 bushels, 1 chaldron; 14 pounds, 1 stone; 21 1/2 stones, 1 pig; 8 pigs, 1 fother; and many more too numerous to mention and most confusing to remember.

As a further illustration of the simplicity of the metric system, I would like to recall a small problem in measurement, worked out both in our old present system and in the metric system. This problem was presented a few years ago in the Washington *Herald*. I might suggest that it would be well to make a note of the problem and at your leisure try it and note the saving of time and its complete simplicity. This is the problem: Find the weight of contained water, the volume, and the capacity of a 6-foot 9 1/2-inch cubic tank. By the old method 243 figures are required f[illegible] calculation, which takes approximately ten minutes' ti[illegible] following are the three answers:

Weight = 19,579.8125 pounds
Volume = 541,343.375 cubic inches
Capacity = 2,343.477 gallons

The same problem in the metric system (each dimensio[illegible] tank is 2.07 meters) requires only thirty-nine figures and takes one to two minutes' time. The three answers all have the same figures:

Weight = 8,869.743 kilograms
Volume = 8,869.743 cubic decimeters
Capacity = 8,869.743 liters

With such a vast difference in favor of the metric system, one naturally wonders why it has not been definitely adopted long ago. The following facts may provide the explanation.

We do not present the system to the general public in its simplest form; we rather confuse the minds of many people by adhering to the use of compound names such as "milli-liter," "kilogram," and "deci-meter," instead of using a few of our present familiar American terms and temporarily using the word *metric* in front of each until the old system disappears entirely from our everyday usage.

As an illustration of this, we may use our present coinage system. If you were to recite our table of coinage using the full metric prefixes, it would run as follows:

10 milli-dollars = 1 centi-dollar
10 centi-dollars = 1 deci-dollar
10 deci-dollars = 1 dollar
10 dollars = 1 deka-dollar
10 deka-dollars = 1 hecto-dollar
10 hecto-dollars = 1 kilo-dollar

But our forefathers, when they adopted our metric system of coinage, streamlined the various terms so that the average person can take to the new system more readily, and the table to this day is as follows:

10 mills = 1 cent
10 cents = 1 dime
10 dimes = 1 dollar
10 dollars = 1 eagle
10 eagles = 1 century
10 centuries = 1 grand

Further to simplify the coinage system, we all use just two of the terms, dollars and cents; no matter what the amount may be, from pennies to billions of dollars, in all transactions of accounts in every business and walk of life, we use just dollars and cents. This is the way we should present to the people the metric system of weights and measures—as simply as possible, in terms of one unit and its hundredth part for each type of measurement.

Now, as an illustration, let us further simplify the use of the metric system of weight, volume, and linear measurement by using only the two necessary units as we do in our system of coinage and temporarily substituting our old names in place of the metric terms. We then have, including our coinage system, the following:

100 cents = 1 dollar
100 ounces = 1 pound
1,000 drams = 1 quart
1,000 inches = 1 yard

Believe it or not, it requires only sixteen words to express our metric system of coinage, weight, volume, and linear measurement, all of which can be written on your thumbnail. When this system comes into use, we can proudly say that our weights and measures system, like our system of coinage, has also advanced to "the height of simplified practice."

An Auxiliary System for the Measurement of Time

FRANK J. MOLES

When the simplicity and utility of the metric or decimal system of measurement of length and weight are considered, it seems strange that there is no equivalent system for the measurement of time. While the convenient metric units are used for length and weight and related measurements, the clumsy and inconvenient 24-hour day is retained with its A.M. and P.M., 60 minutes per hour, and 60 seconds per minute.

It is necessary only to compute the exact time difference between the arrival of a morning train and the departure of an afternoon train to get an idea of the multiple transformations involved and to realize the chances of error in such a time system. In terms of decimal time, however, the time difference would be found by simply subtracting the earlier from the later time.

Suppose you get into New York's Grand Central Terminal at 10:48 A.M. and have to get a train out of the Pennsylvania Station at 2:24 P.M. How much time do you have to change stations, eat lunch, and get your train? First, because 2:24 is P.M., you must add 12 hours, making it 14:24; then you must subtract 10:48. But here special rules have to be used—you cannot subtract 48 from 24, so you must borrow an hour, remembering that it is 60 minutes (not 10 or 100), and set it down thus:

$$\begin{array}{rl} 14{:}24 = 13{:}84 & (84 = 24 + 60) \\ \underline{10{:}48} & \\ 3{:}36 & \text{or 3 hours 36 minutes} \end{array}$$

Now for the decimal system:

$$\begin{array}{rrl} \text{2:24 P.M. would be} & 0.60 \text{ day} & \\ \text{10:48 A.M. would be} & \underline{0.45 \text{ day}} & \\ & 0.15 \text{ day} & \text{(the interval)} \end{array}$$

By simple subtraction we have the answer immediately without any mathematical gymnastics. Furthermore, the computation would be just as simple for any interval, such as

$$\begin{array}{r} 0.723 \text{ day} \\ \underline{0.209 \text{ day}} \\ 0.514 \text{ day} \end{array}$$

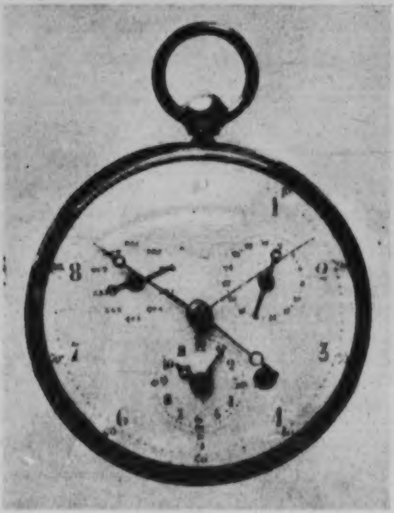
Timetables could be printed all in one kind of type, and that confusion between light and dark numbers could be forgotten forever. The same ease of calculation would apply to workers' clock card time records, to payroll bookkeeping, and to similar tasks.

Incidentally, the decimal intervals can be thought of as per cents of the day or can be read like baseball players' batting averages, which seem easy enough for most sports fans to follow. Thus 0.333 day (which is approximately 8 A.M.) can be thought of as 33 per cent of the day.

If an accuracy is desired approximately the same as that given when seconds are shown in conventional time, it is merely necessary to use more decimal places to the right. For example, 0.49999 day is very nearly the same as 59 minutes and 59 seconds after 11 A.M.

Some strange events in history led to the curious discrepancy between the measurement of length and weight and the measurement of time. The French leaders and scientists of the last part of the eighteenth century appear to have been among the first to appreciate the possible benefits of the decimal system as applied to measurement. Although the system of numbers based on multiples and powers of 10 had been invented long before by some unknown thinker, little actual use had been made of the idea except by mathematicians. The French, however, decided to do something about it and proceeded to establish the metric system in that terrible and troubled decade from 1790 to 1800. The scientists planned and measured and calculated and finally decided upon the meter as the unit of length (it is intended to be one ten-millionth part of the distance on the earth's surface from the Pole to the equator) and upon the gram (the weight of 1 cubic centimeter of water) as the unit of mass or weight. Decimal multiples and submultiples of these units serve as the basis for the metric system. The possibility of dividing time decimally was not overlooked. The months were renamed and divided into ten-day intervals; the days were divided into ten equal parts which were further subdivided decimally. In the heat of those stirring times of the French Revolution, the world was made young again, and September 21, 1792, became the first day of the year 1 of Liberty. This calendar and division of time lasted twelve years, a duration which was surprising enough, since most people undoubtedly used the old calendar and time in secret, if not in public. Certain it is that watches and clocks were made with both old and new time divisions. At least one sample exists today in the United States. This is a watch in the collection of the Smithsonian Institution in Washington D. C., which has both metric and standard dials. It is a very fine example of French skill and workmanship. (See page 228.)

There probably were many reasons why the decimal division of time did not survive along with the meter and the kilogram. First was the fact that time was less important then than now. Length and weight were essential in dealing at the market place, but exact measurement of time was uncommon, and few people thought much about it. The group of ten days in a working period



Decimal watch No. 298951 from Smithsonian Institution, U. S. National Museum, Washington, D. C.

was too long without a rest day and thus made that part of the system exhausting and insufferable, particularly in those days of long working hours. Then, too, the ten-day periods were aimed at eliminating Sundays and Saints' days in the hope of weakening the Church, so this made the whole plan unpopular.

For these reasons, and possibly others, the decimal time system did not come into general use. Between 1791 and 1840, however, there were many laws passed in France to establish the metric units of length and weight. In 1840 the laws imposed penalties for the use of other than metric units, and the new decimal system came into general use in France. As the practical utility of the new system became evident, it was adopted by more and more people, until today it is universally used for scientific measurements and is the standard system of everyday measurement for many countries of the world. It might be used for everyday measurements in the English-speaking countries, also, if it were not for the inertia of habit and the supposed cost of converting tools and equipment to the metric system.

The possibilities of various types of decimal time systems have been considered for many years. A decimal system could be devised in such a way that it could be based on the length of the year, the length of the sidereal day, the length of the mean solar day, or even one of the present smaller time intervals such as the second. Of these possible schemes the most logical and useful appears to be that based on the present mean solar day. This plan would provide units as follows:

0.1 day or deciday (dee)
0.01 day or centiday (cee)
0.001 day or milliday (em)
0.0001 day or decimilliday (dee-em)
0.00001 day or centimilliday (cee-em)

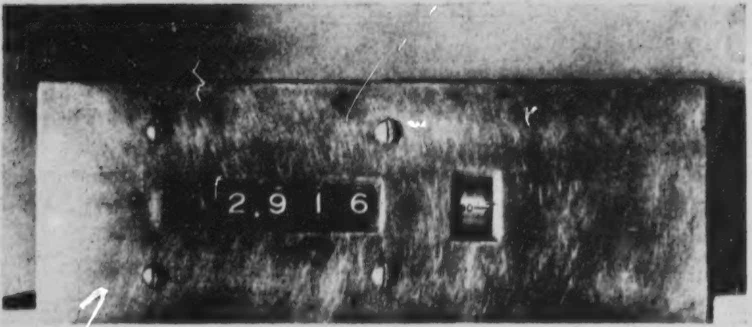
In use the names of these intervals might not be very important, since the part of the day would be read as a decimal, that is, .76521. The first two digits thus may be used to show what per cent of the day has elapsed. However, if names are needed, the abbreviations indicated above could be used, or other brief, distinctive names could be invented.

Comparative values for the new and old units are shown below:

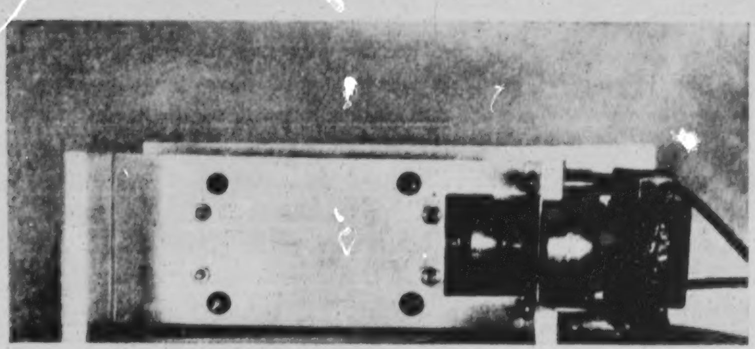
0.1 day or 1 deciday = 2 hours 24 minutes
0.01 day or 1 centiday = 14 minutes 24 seconds
0.001 day or 1 milliday = 1 minute 26.4 seconds
0.0001 day or 1 decimilliday = 8.64 seconds
0.00001 day or 1 centimilliday = 0.864 seconds

Thus it may be seen that the milliday is of a similar order of magnitude to the minute and the centimilliday is of a similar order of magnitude to the second.

Since these are decimal intervals, the part of the day which has elapsed can be indicated directly by a standard decimal counting unit attached by suitable gears to a standard clock motor. The simplest method is to put a twenty-five-tooth gear on the 1-revolution-per-minute shaft of a clock motor and a thirty-six-tooth gear on the shaft of a standard five-digit counter. The first two digits at the left may then be used to indicate days of the month and the next three digits to indicate tenths, hundredths, and thousandths of the day respectively. A dial with 100 equal divisions on the same shaft as the thirty-six-tooth gear then shows ten-thou-



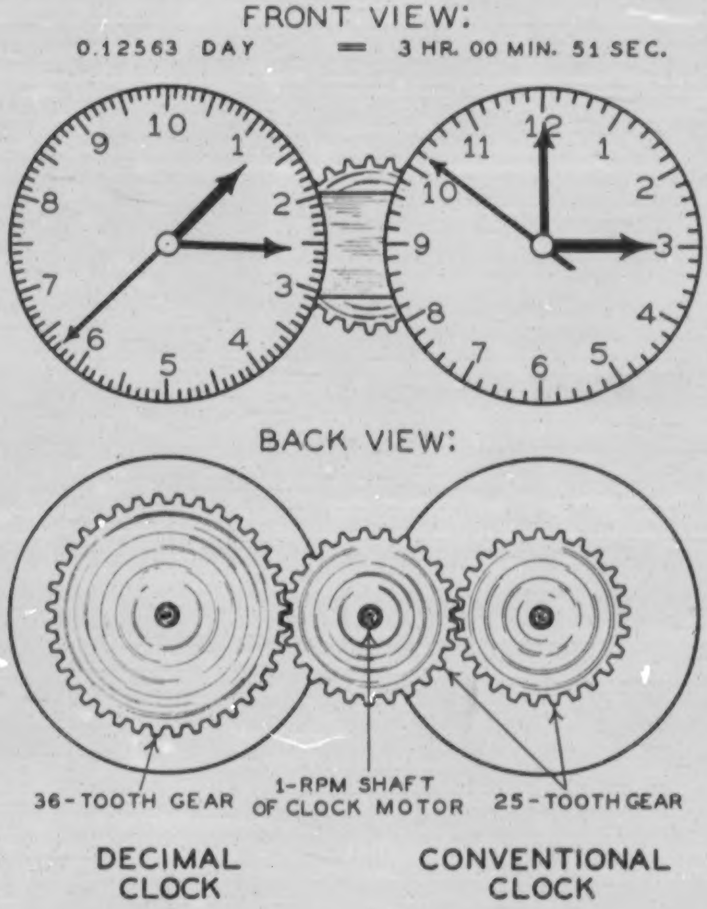
Decimal clock, front view. The first two figures indicate the second day of the month. Almost 92 per cent of the day (0.91691 day) has elapsed.



Decimal clock, rear view.

sandths and hundred-thousandths of the day. Unless some special device is arranged for the left-end digit dial, the indicator would have to be reset at the end of each month. Failure to reset would not affect the accuracy of the figures to the right of the decimal point.

A sample clock has been constructed using this decimal division of the day. It is arranged to be driven by a standard 60-cycle clock and can be operated on commercial 60-cycle systems or on precision 60-cycle standard frequency sources. A similar clock with different gearing could be constructed to run on a precision 1,000-cycle standard frequency source. A clock can also be constructed with two sets of dials or numbers operated by the same


FRONT VIEW:
0.12563 DAY = 3 HR. 00 MIN. 51 SEC.
10
1
2
3
4
5
6
7
8
9
12
11
BACK VIEW:
36-TOOTH GEAR
1-RPM SHAFT OF CLOCK MOTOR
25-TOOTH GEAR
DECIMAL CLOCK
CONVENTIONAL CLOCK

motor, to show both conventional time and decimal time. This would simplify comparisons between systems when necessary.

A clock which would provide both decimal time and conventional time is shown in the accompanying sketch. It is made essentially as follows: A twenty-five-tooth gear is fastened on the 1-revolution-per-minute shaft of a synchronous clock motor (such as a Telechron motor). Another gear with thirty-six teeth which mesh with the twenty-five-tooth gear is connected to a shaft and hand moving around a dial with 100 divisions. Each of these divisions then represents one hundred-thousandth part of a day. This shaft is then geared through a 100-to-1 gear train to another hand moving over a 100-division dial. (This can be just another hand of different length or color, moving over the same dial as before.) These divisions represent one thousandth part of a day. Then the shaft of this hand is connected through a ten-to-one gear train to a hand on a dial with ten divisions. Each of these divisions represents one tenth part of a day. This hand also can be a different length or color moving over the same dial. Two additional ten-to-one gears and hands or numbers can be provided to give the days of the month if desired. This assembly is the decimal time part of the clock. To get conventional time the motor shaft is simply extended and connected to a regular clock movement. Since both systems are geared together, the equivalent of one time system in terms of the other is automatically given by the readings of the hands.

A conventional numeral clock showing digits such as 8:31:27 could also be a driving motor with a decimal clock like the one shown in the photograph. Then both time readings would be shown directly in figures as below:

8:00:00 (A.M.) and 0.33333 day
9:36:00 (A.M.) and 0.40000 day
12:00:00 (noon) and 0.50000 day
2:24:00 (P.M.) and 0.60000 day, and so on

Anyone who is required to measure time differences greater than a few seconds should find the decimal system much faster, simpler to use, and less likely to cause errors, because it eliminates the troublesome multiplications by 60, the additions, and so on. It would seem that the decimal division of time would be of great advantage in astronomical and navigational work. Railroad and other transportation tables could be much less confusing if decimal time were used. Since there are then no A.M. and P.M., this difficulty could be retired to oblivion.

It is interesting to note that Smithsonian tables have for years contained tables for the conversion of hours, minutes, and seconds to decimal parts of a day, and vice versa.

In view of past experiences with attempts to change systems of measurement, calendars, spelling, and other long-established practices, it seems unlikely that there will be any widespread use of the decimal time system. However, the idea is intriguing and may be of some value for special uses, particularly since it is so easy to provide decimal clocks operating on available 60-cycle power sources.

Decimal division of angle is also an interesting possibility. Now we have the clumsy 360° 60′ 60″ system, which is not only awkward in itself but easily confused with time units. For a decimal system the natural unit of angle is 1 revolution, which may be divided into tenths, hundredths, and so on, of a revolution. Thus 90° equals 0.25 revolution, 180° equals 0.50 revolution, and so on. Trigonometric tables can be revised easily to take care of such a system. In fact, there are already many trigonometric tables using such hybrid schemes as degrees and tenths of a degree, or degrees, minutes, and tenths of a minute, and the like.

It is interesting to note that if such a system were used and longitude were measured in it, then decimal time and decimal longitude could coincide exactly. Computations involving time and longitude would be much simplified. There would no longer be any need of converting hours, minutes, and seconds of time to degrees, minutes, and seconds of longitude, or vice versa.

Education

Decimalization of English Measures and Computation with Approximate Data

CARL N. SHUSTER

Down through the ages computation with fractions has been a difficult hurdle for a large portion of the human race. A number of interesting devices have been used to help lessen the difficulty of computing with fractions. The Egyptians restricted their fractions almost entirely to those having unit numerators; the Romans tried to avoid fractions by subdividing their measuring units, thus giving us the topic of "denominate numbers" or "compound numbers"; and other early peoples made extensive use of sexagesimal fractions.

Sexagesimal fractions were so satisfactory that they were employed for a large part of the work in science. The term *common fraction* was used to differentiate fractions of the form *a/b* from sexagesimal fractions.

Our decimal place value number system was developed in India about A.D. 600. By A.D. 1200 or earlier this system reached Spain and very gradually began to displace the cumbersome Roman notation. By the time of Columbus, the Hindu-Arabic decimal notation was in use in southern Europe and from this time on the use of the Roman notation gradually but steadily declined.

It seems strange to us now that it should have taken so long for a number system so obviously superior to displace the Roman system, but the force of mental inertia is perhaps the most formidable of all obstacles to progress. Even a people who, in the span of a single lifetime, have gone from oxcart to jet plane and from the power of the muscles of a sweating slave to the promise of atomic power, and who demand the very latest gadget on their automobiles or radios, will show the stupidity of ignorant taboo-cursed South Sea islanders when asked to change some process or habit to which they have become accustomed. Dozens of examples of the curse of mental inertia may be found in past history, and numerous cases remain to plague us. Decimal fractions, decimal measuring, the metric system, new methods of subtraction, and the reform movement in mathematics are a few examples of superior devices, techniques, or movements held up or impeded by mental inertia. Decimal federal currency was established by law in 1792. As late, however, as 1868, when the Bryant and Stratton *Commercial Arithmetic* was published, the authors considered it necessary to give the currency of all but nine states in terms of English or other colonial monies. Thus in New York the dollar was equal to 8 shillings. In New Jersey, Pennsylvania, Delaware, and Maryland the dollar was equal to 7 shillings 6 pence. In Maine and the other New England states, and in Virginia, Tennessee, Kentucky, and Missouri the dollar was equal to 6 shillings. In North Carolina the dollar was worth 10 shillings, whereas in South Carolina the dollar was worth only 4 shillings 8 pence. In Mississippi the dollar was equal to 8 bits, and in New Orleans the dollar was equal to 16 picayunes. At the turn of the century it was a fairly common experience to find old people who still talked about shillings, and even today the Fulton Fish Market in New York uses shillings in its quotations. The awkward 1/8, 1/4, 3/8, 1/2, 5/8, 3/4, and 7/8 used in stock-market quotations are relics of the day when the dollar was worth 8 shillings and the shilling was 1/8 dollar or 12 1/2 cents. Perhaps in another hundred years the stock-market quotations will be given in dollars and dimes instead of in dollars and shillings. The penny, like the shilling, is an old English coin, and it is not equivalent to the cent. The cent, coined since 1792, has never had the word *penny* on it. Calling the cent a penny spoils the metric relationship: milli-, centi-, deci- of the mill; cent; and dime. The 5-cent piece is never called the 5-penny piece. The newer arithmetics tend to drop the penny or to minimize its use and write 2 cents, 3 cents, 5 cents, 12 cents, instead of 2 pennies, 3 pennies, and so on. This is a thoroughly desirable trend.

It has been pointed out by opponents of the metric system that in metric countries the old measuring units tended to survive. This is not an argument against the metric system, but an illustration of mental inertia. No sane person would suggest that we should go back to the use of the cumbersome English system of money because of the fact that the shilling and penny had survived for more than one hundred and fifty years.

It is difficult to say when decimal fractions were invented, but Rudolff (1530) and Simon Stevin (1585) are entitled to most of the credit for bringing decimal fractions to the attention of the world. Both Rudolff and Stevin had awkward techniques for writing decimal fractions, but Stevin, at least, fully understood decimal fractions and thoroughly appreciated their advantages over common fractions. In addition he suggested a full set of decimal measures. In *La Disme* Stevin says, "All measures—linear, liquid, dry, and monetary—may be divided decimally" [11].[1]

It is sad to contemplate the millions of years of time that have been wasted by individuals because of the mental inertia that prevented, for so long a time, the adoption of Stevin's suggested decimal fractions and measures. For two hundred years the use of decimal fractions was confined largely to logarithms and to other tabulated data. In 1792 decimal fractions increased greatly in importance when the United States abandoned the English monetary system and adopted a decimal system of coinage in its place. In 1799 the decimal movement received further impetus when the French Government adopted the metric system. In 1866 the metric system was made legal in the United States, and later, in 1893, the meter was adopted as the official standard of length in this country, the yard being defined in terms of the meter.

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[1] Numbers in brackets refer to items in the Bibliography at the end of this article.

Very soon after the legalizing of the metric system, various trades and professions began to divide our old English units decimally. The National Bureau of Standards reports: "Level rods with decimal graduations of a foot were in general use at least 60 years ago." Micrometer calipers with decimal graduations of the inch have been used for fifty years or more, and steel tapes graduated in feet, 0.1 foot, and 0.01 foot have been in general use for at least twenty-five years. The mile, the pound, and the hour are other measuring units that have for a long time been decimalized, and averages are almost always given as decimals.

It is hard to realize the extent to which decimalization of our measures has progressed. In a recent issue of the *Country Gentleman* there were 179 decimal fractions aside from United States money. Among the decimal fractions appearing in this issue were the following: 2.25 gal., 1.75 grams, 8.75 in., 49.9 lb., 2.9 m.p.h., 11.4% water, 5.4 oz., milk test 4.32%, 24.6 drawbar horsepower, 339.5 million bushels, 99.7 calories per ounce. Other decimal fractions found in recent farm publications are: 2.8 mm., 24.6 oz., 87.8 acres, 308.6 gal., 0.000025 in., 14.6 mi., 5.67 ct. per k.w.h., 11.38 miles per gallon, water flow of 3.75 ft. per sec., 27.85 points (egg contest), 9.8 (peony rating). There were also statements that "at four months an Ayrshire should weigh 2.66 times its birth weight, a Guernsey 2.72, a Holstein 2.75, and a Jersey 3.04"; "milk weighs 2.15 lb. per quart"; "the milk test was 4.24"; and "this lister cultivator is 6.7 feet wide and at a speed of 3.3 miles per hour will cultivate 2.7 acres per hour." Recent farm bulletins contain thousands of decimal fractions in a wide variety of units.

Another trend toward decimals is the growing tendency to sell bulbs and other things by tens, hundreds, and thousands, in place of the dozen, gross, and great gross, and to sell produce by the 100 pounds in place of the bushel.

In engineering and in many other phases of industry, decimalization of measures is taking place even more rapidly than in agriculture. The numerous illustrations from agriculture were selected to show the decimal usage in an area where it has been widely believed there was little need for decimal fractions.

Unfortunately, some colleges still grant degrees to students who make a cursory study of the usage in certain fields of trade and industry and then in the light of their findings recommend the elimination or curtailment of this usage as a topic of study in the schools. If this were our sole criterion for subject matter, there would be little growth or improvement in education. Very often the important question is *what should be used* instead of *what is used*. This is especially true in connection with the topics of decimal measuring and the metric system.

The adoption of decimal fractions and decimal measuring units has been held up to a considerable degree by the stupid examples formerly found in our early textbooks. In an arithmetic published in 1895 and used well into the present century [5] the following are given:

1. Reduce to a common fraction: .194805 15/17
2. Multiply 1.08096 × 3.5702. Ans. 3.859243392. [The last five digits are not significant.]
3. Reduce 113/256 to a decimal fraction. Ans. 0.44140625.
4. Divide 273.2879688 by 6.072. Ans. 45.0079.

In arithmetics published in the nineteenth century, examples in decimal fractions can be found with answers containing from sixteen to sixty digits. Pupils exposed to such examples could not be expected to see the advantage of decimal fractions.

If, in place of the examples cited above, pupils had been asked to work a series of paired problems like those below, it is safe to assume that decimal fractions and decimal measuring would have been adopted many years ago.

1. *a.* A building lot is 248 ft. 7 3/8 in. by 84 ft. 5 7/8 in. What is its area?
   b. A building lot is 248.61 ft. by 84.49 ft. What is its area? Round your answers in *a* and *b* so that all the digits retained will be significant.
2. *a.* A turkey weighs 17 lb. 5 oz. What will it cost at 47 1/2¢ a pound?
   b. A turkey weighs 17.3 lb. What will it cost at 47.5¢ a pound?
3. *a.* A man begins work on a job at 8:45 A.M. and quits at 11:09 A.M. What should he receive at 87 1/2¢ an hour?
   b. A man begins work on a job at 8.75 A.M. and quits at 11.15 A.M. What should he receive at 87.5¢ an hour? [Note: a decimal time clock is used in *b;* 8.75 means 8 and .75 hours.]

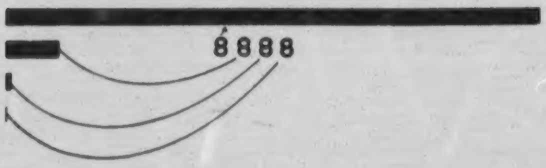
Far too many abstract decimal fractions are found in current texts. These are relatively rare in life. If decimal fractions are to be real and have meaning, they should grow out of measuring experience with instruments graduated decimally.

When decimal measuring units are used, it is very easy to apply the necessary rules for computing with approximate data. This is one of the best reasons for adopting decimal measuring units. With our old units it is difficult to apply the rules for computation of this kind.

These rules are just as necessary when data are given in our old units as when data are given in decimal units, but unfortunately, as the result of ignoring them, from 40 per cent to 90 per cent of the answers to the practical problems found in many mathematics and science texts are wrong. Ignorance may be bliss, but it has no place in mathematics and science texts.

COMPUTATION WITH APPROXIMATE DATA

Computation with approximate data is needed in a large proportion of the problems of life, since these problems contain approximate data secured from measurements or taken from various handbook tables. The table on the properties of saturated steam



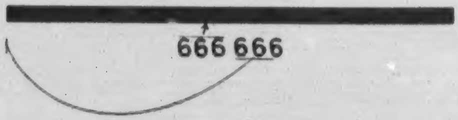
A

in the *Handbook of Physics and Chemistry* [9] contains 3,591 approximate factors, and there are hundreds of similar tables in the numerous handbooks. In solving problems containing approximate data, one should always follow the laws for computing with approximate data.

Approximate data are used in many phases of the mathematics and science taught in the elementary and secondary schools. It is not at all difficult to teach the rules for computing with approximate data in the seventh, eighth, and ninth grades. In fact, it is easier to teach the fundamental facts of this topic in these grades than it is to change the computational habits and concepts of graduate students who have always used "exact" computation. The rules for computing with approximate data should be taught at the earliest opportunity and then constantly used in all subsequent work in mathematics and science.

Pupils can measure to the nearest foot, to the nearest 0.1 foot, or to the nearest 0.01 foot, according to the graduations on their tape and the care with which it is used, but they cannot measure any length exactly. There are at least ten sources of error in measuring so simple a thing as the distance between two points several hundred feet apart. Pupils should learn that no one in the whole history of the world has ever made an exactly accurate measurement of any length. The same is true of measurements of time, weight, volume, area, temperature, rotation, latitude, longitude, and the like. The most accurate measurements ever made do not have more than eight significant digits, and most of the measurements used in industry have from three to five significant digits.

Figure A shows how slight is the relative value of the last digit of a four-digit number. If this number had been rounded to 8,890, the change in the third bar would have been too small to notice.



B

Figure B shows how small is the relative value of the last three digits of a six-digit number. Three- and four-digit results are highly satisfactory for most purposes. The astonishing popularity of the slide rule in industry and engineering is due to this fact.

Fundamental Concepts. Pupils should be taught the meaning of *unit of measurement* and *significant digits* and *how to round numbers* and *when* and *why* this is necessary. The *unit of measurement is the smallest unit used in a measurement.* The *unit of measurement* in the following measurements is given in the parentheses: 64.32 feet (0.01 foot); 43.8 feet (0.1 foot); 34.3 pounds (0.1 pound); 16 pounds 12 ounces (1 ounce); 34°24′16″ (1″); 16 3/8 inches (1/8 inch); 6,843 miles (1 mile); 10.2 seconds (0.1 second); 2.1034 inches (0.0001 inch).

If a distance has been measured so accurately that it is known to be nearer to 986.3 feet than it is either to 986.2 or to 986.4 feet, the measurement has four significant digits. *For all digits of a number to be significant, every digit except the last must be correct, and the error in the last digit must not be greater than one-half the unit of measurement.*

If the measurement 26.8 inches has three significant digits, it must be between 26.75 inches and 26.85 inches. If the measurement 165.37 feet has five significant digits, it must be between 165.365 feet and 165.375 feet. Zeros that are the result of correct measurement are significant. If the measurement 300 feet is correct to the nearest foot, or lies between 299.5 feet and 300.5 feet, the measurement has three significant digits and the two zeros are both significant. Zeros should not be written after a decimal point in a mixed decimal unless they are significant. One can be sure that the measurement 26.00 feet has four significant digits and that the measurement 3.0000 inches has five significant digits.

Zeros used to give the correct place value in a rounded number are not significant. If 186,284 is rounded to 186,000, the three zeros are not significant. Zeros are also used before significant digits in a decimal fraction to give correct place value. Zeros used in this way are never significant. If the three-digit measurement 86.3 millimeters is changed to 0.0000863 kilometers, it is evident that the zeros are not significant.

Various devices have been suggested to indicate when zeros are significant, but in most cases special devices are not necessary. In a set of measurements one can usually tell which zeros are significant.

In the set of measurements below it is safe to assume that the zeros are significant.

$$\begin{array}{rl} 3000 & \text{feet} \\ 4123 & \text{"} \\ 1300 & \text{"} \\ 2177 & \text{"} \\ \hline 10600 & \text{feet} \end{array}$$

Like people, zeros may be judged by the company they keep. If one sees such measurements as 6,000,000,000,000 miles or 186,000 miles, one may usually assume that these are rounded numbers and that the zeros are not significant.

Pupils who secure their own data through measuring will always know which zeros are significant. No author should ever give a rounded number in a problem without telling the number of significant digits; for example: The speed of light, correct to three digits, is 186,000 miles per second. How long will it take light to go 7,927 miles? Or the speed of light is 186,300 miles per second (4 significant digits), or, using scientific notation, 1.863×10^5 miles per second.

To find how many significant digits there are in a measurement when decimal measures are not used, express the measurement in terms of the *smallest unit of measurement used.* Thus, 46° has two significant digits; 9 inches has one significant digit, but 9 0/64 inches or 576/64 inches has three; 68 pounds 4 ounces or 1,092 ounces has four significant digits; 9 feet has one significant digit, but 9 feet 0 inches or 108 inches has three significant digits, and 9 feet 0/32 inches or 3,456/32 inches has four significant digits.

When changing measurements containing common fractions to decimals, retain only the same number of significant digits as there are in the original data. Thus 6 3/8 inches or 51/8 inches (2 significant digits) is not equivalent to 6.375 inches (4 significant digits), and 2 2/3 inches or 8/3 inches (1 significant digit) is most certainly not equal to 2.667 inches (4 significant digits). There may be an error of one-half the unit of measurement in 6 3/8 inches. Since the unit of measurement is 1/8 inch the error may be as much as 1/16 inch or 0.06 inch. With the possibility of an error this large, no careful or honest computer would change 6 3/8 inches to 6.375 inches. It must be remembered, however, that abstract hypothetically exact fractions may be carried out to as many digits as is desired. The 1/3 that appears in the formula for the volume of a cone may be carried out to ten or more digits if this accuracy is desirable. Actually it should be carried out to one more digit than the number of digits in the least accurate measured data with which it is used. Also, all the fractions in the series, 1/2, 4/8, 32/64, 64/128, 0.5, and 0.5000000 are equivalent provided they are exact, abstract fractions. If the above fractions are measurements, they are not equivalent.

Common fractions are very unsatisfactory in real life computation because of the difficulty of finding the number of significant digits when they are used and because of the fact that they cannot be used conveniently with slide rules, computing machines, or logarithms, in tables, or for the very precise measurements common today. They are also less convenient to type and print than decimal fractions and are more difficult to use in pencil computation. Computation with decimal fractions can be taught much earlier than computation with common fractions. For these and a number of other reasons decimal fractions are rapidly replacing the old-fashioned common fractions. In fact, the time is rapidly approaching when any extended computation with common fractions may well be held over for algebra.

Arithmetics in which all computation was done with decimal fractions were written more than one hundred years ago [14]. At that time there were no decimal measuring instruments, the use of decimal money was still far from being universal, and there was no demand from science and industry for exceedingly precise measurements. Because of these facts there was no possibility that wholly decimal arithmetics could succeed. Today, however, such arithmetics would be thoroughly practical and distinct improvements over existing arithmetic texts.

Rounding Numbers. All elementary texts teach pupils *how* to round numbers, but they usually *do not teach* them the really important concepts and practices: *when* to round numbers or *why* the answers to certain problems must be rounded, and *how to determine the number of digits to retain* when rounding data or answers. Some situations in which it is desirable or necessary to round numbers follow: (*a*) In constructing graphs, it is usual to round data to two, three, or, in very large graphs, four significant digits. (*b*) Data obtained from handbooks may be more accurate than are needed to work a problem. Thus, the value of π to six digits is 3.14159. To find the circumference of a circle 8.6 feet in diameter, π should be rounded to 3.14, or to one digit more than the data. All conversion factors and similar data are rounded in this manner. (*c*) Data to be learned are usually rounded. Thus the speed of light is usually rounded from 186,284 miles per second to 186,000 miles per second; the diameter of the earth at the equator is usually rounded from 7,926.8 miles to 8,000. miles; the acceleration due to gravity at sea level (latitude 45°) is usually rounded from 32.172 feet per second to 32 or 32.2 feet per second; and the length of the light year is usually rounded from 5,875,156,800,000 to 6×10^{12}. (*d*) Computation usually introduces digits that are not significant. Such spurious digits must be rounded off. (*e*) If an answer accurate to only n digits is desired, it is customary to round all data to $(n + 1)$ digits before computing. Some authorities round to $(n + 2)$ digits. Later in this article rules are given to determine the number of digits to be retained in rounded answers.

The following rules may be used for rounding numbers:

1. If a number, correct to a certain number of significant digits, is to be rounded to a smaller number of significant digits, the digits that are dropped should be replaced by zeros. When the digits that are dropped are located to the right of [illegible] decimal point, they should not be replaced by zeros. Thus the polar radius of the earth, 3,949 miles, rounded to two digits is 3,900 miles; but 1° of latitude at the poles, 69.41 miles, rounded to two digits is 69 miles.

2. If the first of the digits that are to be dropped is 5, 6, 7, 8, or 9, the last digit retained should be increased by 1. The mean distance from the earth to the moon, 238,854 miles, rounded to three significant digits is 239,000 miles; and 1° of latitude at the equator, 68.71 miles, rounded to two significant digits is 69 miles. Some texts say that when 5 is dropped, the preceding digit should be increased by 1 if it is odd but left unchanged if it is even. About the only advantage of this rule, if used, is that all students will round in the same way. Since there are as many even as odd digits, when a large number of addends are summed, the errors will tend to compensate. If this rule is used, it should be used only for limited cases of 5, 50, 500, 5,000, and so on. If some number such as 234,512 is to be rounded to three digits, the third digit should be increased by 1 whether it is odd or even.

Adding and Subtracting Approximate Numbers. In a set of measurements like those shown in *a*, each measurement should be given to the same unit; in this case the tenth of a foot is the unit of measurement, since each measurement is made to the nearest tenth of a foot.

a.	42.6 feet	*b.*	26.24 feet	*c.*	9 8/16 inches
	80.0 "		30.00 "		4 3/16 "
	76.3 "		16.36 "		5 1/16 "
	8.0 "		41.30 "		3 0/16 "
	206.9 feet		113.90 feet		21 12/16 inches

In set *a*, the zeros are significant and must be written as shown. In set *b*, since the unit of measurement is 0.01 foot, the zeros are significant and cannot be omitted. In set *c*, the unit of measurement, 1/16 inch, is clearly indicated. The 8/16 inch should not be reduced to 1/2 inch. The 0/16 is necessary to show the same unit has been used for each measurement. The 3 0/16 in *c* is just as necessary to show that this measurement is accurate to the nearest 1/16 inch as is the 8.0 feet in *a* to show that this measurement is accurate to the nearest 0.1 foot. There is a vast difference between exact, abstract fractions and the concrete fractions obtained by measuring. The fractions obtained by measuring are never exact and must be treated as all approximate data are treated. The last digit of each measurement in *a* and *b* is a nearest digit and may be slightly too large or slightly too small. For reasons given above, the last digit of the answers to *a*, *b*, and *c* may not be significant, but in practical work the best rule is to retain the full answer. If the 12/16 in the answer to *c* is reduced to 3/4 inch, the indicated accuracy of the answer will be reduced from three significant digits to two significant digits, the precision of the measurements will be lessened, and an important part of the original data, the unit of measurement, will be lost.

In subtracting approximate numbers it is better to retain the full answer, as shown in *d*. Quantities to be added or subtracted should be measured to the same unit. Sometimes it is necessary to add measurements made by different people or measurements and results obtained from computation. In these cases it may be necessary to round the data to the same unit before adding.

d. 86.24 inches	*e.* 251. feet	*f.* 3. inches
23.41 "	32.641 "	1.8762 "
62.83 inches	4.37 "	
	120.5 "	

Unfortunately examples in addition and subtraction like *e* and *f* may still be found in certain textbooks and in examinations containing obsolete processes. The pupil is usually instructed to "fill the empty places with zeros and then add or subtract." Examples of this type do not occur in real life, and they should not appear in up-to-date books. Reeve says, "Not only is an example like 12.7 — 4.0396 a non-essential, but it is an evidence of educational ignorance" [13].

Writing about similar examples found on so-called standard tests (9.4 — 4.00083 and 9.2 — 3.00061), Upton says, "How is a teacher to keep her balance when presumably authoritative tests give problems like the above?" [15]. Brueckner and Grossnickle say in connection with similar examples, "The teacher who gives examples of this type is defeating one of the purposes of teaching decimals. Neither business nor science uses such procedures." And, again, "Ragged decimals never occur in social usage" [6].

It should be noted that if the zeros in an example like the following are not significant, the example violates the rule that all measurements to be added or subtracted should be measured, or rounded, to the same unit. This is another case of "ragged decimals."

46	feet
210	"
3,400	"
163,000	"

Examples *e* and *f* *violate the fundamental rule that all measurements to be added or subtracted should be measured to the same unit.* Certainly no experienced person would think of using four different units in one set of measurements. No one uses a yardstick for part of a set of measurements and a micrometer for the balance.

Computation never increases the accuracy of the data. Cullimore says, "The frequent habit of carrying results to a greater number of significant figures than the data warrants comes perilously near to lying with figures" [7]. The teacher who annexes zeros in examples like *e* and *f* and thus makes people believe that rough data are very accurate data is no longer "perilously near"; he has arrived. It is *never permissible to annex zeros* in examples like *e* and *f*. The measurement 251 feet in *e* may be anything between 250.500 feet and 251.500 feet; therefore 251.000 feet is only one of a thousand possible values, each of which would produce a different answer.

A measurement like 3 inches (*f*) is a very rough measurement, whereas 3.0000 inches is a very precise (small unit) and accurate (five significant digits) measurement. In no sense are 3 inches and 3.0000 inches equivalent. If the 3.0000 inches has been measured correctly to the nearest 0.0001 inch the zeros are significant and no practical measurer would omit them. *Zeros should never be annexed in addition or subtraction.*

Criteria for Accuracy. The measurements 4,832 feet, 48.32 feet, and 0.4832 feet are all equally accurate, since they have the same number of significant digits; but the last measurement is the most precise, since it has a much smaller or more precise unit of measurement. An instrument of precision was needed to make the last measurement. A measurement or the answer to a problem must have the decimal point correctly located, but the location of the decimal point does not indicate the accuracy of a measurement or the accuracy of an answer. Many texts instruct pupils to carry out answers in division to a stated number of decimal places. This is not a satisfactory criterion and often leads to serious errors.

The two examples below are taken from a set of examples having the instructions, "Carry your answers out to the nearest hundredth":

$$a.\ \begin{array}{r} 3{,}865.74 \\ 2.16\,\overline{)\,8{,}350.} \end{array} \qquad\qquad b.\ \begin{array}{r} .02 \\ 83.61\,\overline{)\,1.432} \end{array}$$

In *a* the answer should be carried out to four digits and rounded back to three; 3,870. is the best answer. In *b* the answer should be carried out to five digits and rounded back to four; 0.01713 is the best answer. The ridiculous answers obtained by carrying out the instructions show how unsatisfactory such instructions are. It is true that a careful textbook writer will avoid such absurd extremes, but his examples will be highly artificial, since he must juggle all his data to make them fit the instructions.

The only safe criterion is, *carry the answer out to, or round the answer to, the number of significant digits justified by the data.*

The criterion for accuracy that is easiest to apply in the ordinary computation used in elementary schools and in high schools, is the number of significant digits. This criterion is satisfactory for all but the most refined scientific computation. Changing the three-digit measurement 86.3 millimeters to 0.0000863 kilometer does not change the accuracy of the measurement. Since 86.3 millimeters and 0.0000863 kilometer each have three significant digits, they are of the same degree of accuracy. *A measurement having three significant digits, or three-digit accuracy, is more accurate than a measurement having two significant digits, or two-digit accuracy.* An approximate number having four significant digits, or four-digit accuracy, is more accurate than one having three significant digits, or three-digit accuracy. An approximate number having $(n + 1)$ significant digits is more accurate than one having only (n) significant digits.

If two measurements have the same number of significant digits, the one that begins with the larger digit is the more accurate. Thus 8.76 feet is more accurate than 342. feet, 4.37 feet, 0.135 feet, or 63.8 feet. The measurement 99.9 feet is very near to four-digit accuracy (99.9 + 0.1 = 100.0), whereas the measurement 10.0 feet has just got into the three-digit class (9.9 + 0.1). If there is an error of 0.05 feet in each of the last two measurements, the error in the first is 0.05 in 99.9 or 1 in 1,998, whereas the error in the second is 0.05 in 10.0 or 1 in only 200. It is easily seen that the error in the second measurement is far more serious than the error in the first. *The ratio of the error in the measurement to the measurement itself is called the relative error.* Where a rigorous criterion for accuracy is needed, the relative error should be used.

The smallest whole number with two digits is 10, and the largest is 99. Since the unit of measurement is 1, the maximum error to allow two significant digits in each of the above numbers is 0.5. The relative errors will be roughly 0.5/10 = 0.05 = 5 per cent and 0.5/99 = 0.005 ≐ 0.5 per cent. That is, in a number with two significant digits the error will range from 5 per cent down to 0.5 per cent. The location of the decimal point will not affect the range of the error. The numbers 99, 9.9, 0.99, and 0.00099 will all have the same relative error.

The range of error for numbers with more than two significant digits may be found in the same way. The table below shows the range of errors for numbers of two to five significant digits.

Number of Significant Digits	*Range of Error in Per Cent*
2	5 to 0.5
3	0.5 to 0.05
4	0.05 to 0.005
5	0.005 to 0.0005

The measurement 4 0/16 inches or 64/16 inch may have an error of one-half the unit of measurement, or an error of 1/32 inch. Since 1/32 ÷ 64/16 = 0.0078 or 0.78 per cent, this falls in the two-digit range and *checks the approximate rule given earlier in this article for finding the number of significant digits when decimal units were not used.* Again, an error of 0.5 ounce in the measurement 12 pounds 4 ounces or 196 ounces will be 0.5 in 196. Since 0.5 ÷ 196 = 0.0025 or 0.25 per cent, the measurement has an error between 0.5 per cent and 0.05 per cent and is in the three-digit class.

The expert always writes the full dimension. No designer, draftsman, or engineer would write 2 inches when he intended a dimension to be 2.0000 inches. In addition to this, the tolerance (the amount of variation permitted in the size of a part) is usually given. If a shaft is to fit in a hole, the dimensions might be given as follows:

$$\text{Hole } 2.000 \text{ inches } \begin{array}{l}+\,0.001\text{ inch}\\-\,0.000\text{ inch}\end{array} \qquad \text{Shaft } 1.999 \text{ inches } \begin{array}{l}+\,0.000\text{ inch}\\-\,0.001\text{ inch}\end{array}$$

That is, the hole can vary from 2.000 inches to 2.001 inches, and the shaft can vary from 1.998 inches to 1.999 inches. An engineer would never write 46° for 46° 0′ or 46° 00′ 00″ (either form is permissible). The U. S. Coast and Geodetic Survey goes so far as to write 100° 00′ 00.0″ when a position has been located to the nearest 0.1 second of latitude or longitude.

In contrast to the correct and scientific practice followed by the technicians, the average person very often gives only part of the measurement. Thus a man wanting a table of a certain size, such as 4.00 feet by 6.00 feet, or 4.000 feet by 6.000 feet, or 4 feet 0/8 inch by 6 feet 0/8 inch, or 4 feet 0/64 inch by 6 feet 0/64 inch, will usually write the dimensions 4 feet by 6 feet. It is, of course, impossible to build a table "exactly" 4 feet by 6 feet, but since it is relatively easy to measure to three- or four-digit accuracy, a carpenter building the table will most certainly not have an error of 0.5 foot in either dimension. It is reasonable to assume that the error will not be greater than 1/16 inch in such a piece of work by an experienced craftsman.

If the rules for computing with approximate data are followed, the area of a table 4 feet by 6 feet would have to be rounded to one-digit accuracy. The answer 24 square feet would be rounded to 20 square feet. It is obvious, however, that since the *intended* accuracy is at least that indicated by dimensions of 4.0 feet by 6.0 feet and doubtless by dimensions of 4.00 feet by 6.00 feet, the answer 24. square feet or even 24.0 square feet is a better answer than 20 square feet. The trouble is not with the rules for computing with approximate data but with the careless way in which the data were given.

A carpenter wishes to buy a door "exactly" 4 feet by 7 feet. If the door is 1/16 inch short, he will doubtless have no objection, and if it is 1/16 inch to 1/8 inch too long for his opening, he will plane it off and be happy.

When our elementary textbooks begin to give their data correctly and to teach pupils how to use these data correctly, we will have far better mathematics in the elementary schools and far better preparation for high school mathematics and science and for real life applications.

Rules for Multiplying and Dividing Approximate Numbers. When two approximate numbers are to be multiplied or divided, the following rules should be used:

1. *If two approximate numbers have the same number of significant digits, multiply the numbers and round off the product to the same number of digits as there are in each factor.* The last digit of the answer will not always be significant, but this rule is satisfactory for all elementary work and is usually followed in scientific work. For example, 26.3 × 9.25 = 243.275. This result should be rounded to 243.

2. *If one of two approximate numbers has more significant digits than the other, first round off the more accurate approximate number so that it contains one more significant digit than the less accurate approximate number. Then multiply the numbers and round off the product to the same number of digits as there are in the less accurate factor.* A product can never have more significant digits than there are in the least accurate of the factors used in the computation, and in some cases it may have one less significant digit; but for elementary work the rules given above should be used. For example, 34.5 × 42.1555 = ? should be worked as 34.5 × 42.16 = 1,454.520. This result should be rounded to 1,450. The zero is not significant.

3. *If two approximate numbers in division have the same number of significant digits, carry the quotient out to one more digit than is contained in each of the given numbers. Then round off the quotient so that it contains the same number of digits as there are in each of the given numbers.* For example, 153 ÷ 62.5 = 2.448. This result should be rounded to 2.45.

4. *If the dividend and divisor are such that one of them has more significant digits than the other, first round off the more*

accurate number so that it contains one more significant digit than the less accurate number. Then divide and carry the quotient out to one more digit than is contained in the less accurate of the two numbers. Finally round off the quotient to the same number of digits as are found in the less accurate number. Thus in the example 884 ÷ 2,150.42, round to 884 ÷ 2,150 = 0.4111; then round the answer to 0.411. Note: 884 ÷ 2,150.42 = 0.41108, which also rounds to 0.411.

When the above rules for dividing approximate numbers are used, the last digit of the quotient will not always be significant, but these rules are satisfactory for all elementary work and are usually followed in work in science.

The four rules given above may be combined into a single rule. *In multiplication and division the answer can never have more significant digits than there are in the least accurate factor. Answers should be rounded to the same number of digits as there are in the least accurate factor.*

Rules 2 and 4 may save considerable unnecessary computation, especially in texts where the author has not used consistent data, but they are not essential and consequently may be omitted if desired.

A rough demonstration like the one below will help to show the reasonableness of the laws for multiplication. The uncertain digits are in boldface. All digits obtained by using these uncertain digits are also shown in boldface, except those combined with digits carried from the boldface digits. The problem is: What is the area of a rectangle 8.65 feet by 7.43 feet?

8.65
7.43
2595
346**0**
605**5**
64.**2695** Best answer 64.**3**

It is evident that it would be deceptive to retain more than one uncertain digit. This device may be used for multiplication or division. Pupils may use red pencil for the uncertain digits. A second demonstration is to take the product of the two lower limits (8.645 × 7.425) and the two upper limits (8.655 × 7.435) and round the answers to three digits. If all the possible combinations between these limits are taken, there will be 11 × 11 or 121 different answers. Any one of these may be *the* answer. If, however, Rules 1 and 2 are followed, the best answer will be obtained in a very large per cent of the cases, and in most of the other cases the error in the last digit of the rounded answer will seldom be more than 1. In a very few cases it may be 2 or even 3. It is far better to run the risk of a small error in the last digit in a very small per cent of the cases than to follow the present plan of retaining two, three, four, or more digits that are not significant or the equally serious error of dropping digits that are significant.

5. *In the actual work of dividing two approximate numbers, it is sometimes necessary to annex zeros to the dividend in order to secure in the quotient the number of digits warranted by the original data.* In the example 86.2 ÷ 9.43 the answer should be carried out to four digits and rounded back to three (the answer is 9.14). To secure this answer it is necessary to annex several zeros. If the dividend in such cases is more accurate than the divisor, the original digits may be retained instead of following Rule 4. *The zeros annexed in division do not affect the accuracy of the digits retained by following Rules 3 and 4.* Four zeros were annexed to get the answer 9.141, which was rounded to 9.14. The same answer may be obtained by rounding to three digits the quotient obtained by dividing any of the following numbers by 9.43: 86.20000, 86.21111, 86.21234, 86.23333, 86.21987, 86.18888, 86.19999, or any one of several hundred other numbers obtained by annexing digits other than zero. In any of the above cases the annexed digits enable the computer to get the number of digits to which he is entitled by the rules that have been given, but they do not change the first three digits of the answer. *In actual practice the only digit ever annexed is zero.* If this same test is made in addition or subtraction, a large array of different answers will be obtained. *It is never permissible to annex zeros in addition or subtraction.*

6. *The answer in square root should contain the same number of significant digits as there are in the approximate number whose root is sought. The square root of 64 is 8.0, and the square root of*

64.00 is 8.000. It is better to carry the answer out one digit farther than warranted and then round back as was done in division. Both the 64 and the 64.00 used above were assumed to be approximate numbers. The square root of an *exact number* may be carried out to as many digits as desired. In practical work this will usually be determined by the other data in the problem. If the root is to be used with data of n significant digits, it should be rounded to $(n + 1)$ significant digits.

7. *When used in multiplication, division, and square root, the rules for computing with approximate data should be applied only to the approximate factors.* The 4, 3, 1, 2, 6, and 4 in the following formulas are exact numbers:

$$V = 4/3\,\pi r^3;\ A = 1/2\,ab;\ V = h/6\,(B + 4m + T).$$

Pupils must be trained to differentiate between exact and approximate numbers.

Exact Numbers. 1. *Numbers obtained by counting are considered exact.* This is especially true when the elements counted are practically identical, such as six nickels, eight 1-inch steel balls, twelve standard eggs of the same grade. When the elements counted are not identical, the "measurement" may be *wildly approximate for some purposes.* If a new development contains eighty-six houses all built from the same set of plans and costing [illegible],600 each, the 86 may be considered an exact number. However, if there are in a town eighty-six houses ranging in value from a mansion costing $95,000 down to a shack costing $800, the 86 is exact only in a "census" sense.

Large numbers obtained by counting should be carefully checked to see that counting produced no error. If we read that a certain city has 2,276,385 inhabitants, we may be sure, for a number of good reasons, that little confidence can be placed in the last two or three digits.

2. *Small whole numbers in various formulas are almost always exact.*

3. *Hypothetical measurements may be considered exact.* If the sides of a square were exactly 2 inches, the perimeter would be exactly 8 inches, the area would be exactly 4 square inches, and the diagonal $2\sqrt{2}$ inch. The $\sqrt{2}$ in this case could be carried out

to any desired number of significant digits. It might be well to note, however, that no one could construct such a square or measure its sides exactly if it did exist. A hypothetical square foot 12 inches by 12 inches contains 144 square inches, and a hypothetical cubic foot 12 inches by 12 inches by 12 inches contains 1,728 cubic inches.

Approximate Numbers. 1. *All measurements of all kinds are approximate.*

2. Ratios of measured results are approximate.

3. Many numbers, or ratios, such as 2/3, π, e, $\sqrt{3}$, $\tan x$, and so on, cannot be expressed exactly by an ordinary mixed decimal or decimal fraction. *When the first n digits of such a number are taken as a satisfactory approximation, the number thus obtained is approximate.*

4. *All rounded numbers are approximate.* The answer to any problem in which approximate data are used is approximate and must be correctly rounded.

5. *Practically all the numbers taken from various handbook tables are approximate.* There are hundreds of such tables, some of which contain thousands of approximate numbers.

6. It is fairly safe to assume that practically *all mixed decimals* and *decimal fractions* are approximate.

Miscellaneous Rules and Suggestions. When such approximate numbers as π, 0.7854, 1.732 (the $\sqrt{3}$), e, or any of the thousands of physical constants, ratios, and reduction or conversion factors found in the various handbook tables are used in a formula or problem, *round off the value found in the table to one more significant digit* than is contained in the least accurate of the other approximate numbers in the formula or problem. This agrees with the rules for multiplying and dividing approximate numbers and for partial products. A text should never say $\pi = 3.14$, or $\pi = 3.1416$, or the like. The only satisfactory procedure is to round to eight significant digits, making $\pi = 3.1415927$. The pupil should then be taught to round this value to one figure more than his data. Eight significant digits were chosen because an eight-significant-digit measurement is the most accurate measurement that has been made up to the present time. The value of π could be given, of course, to six, seven, eight, or as many digits as are desired. The value given should contain more digits than any of the data given in the text. The same thing should be done with conversion factors, that is, 1 kilometer = 0.62136995 mile, 1 liter = 1.0566818 liquid quarts, 1 kilogram = 2.2046223 pounds, and so on. The value given should always be sufficiently accurate for any measurement that will ever be needed in the text. Note: Technically it would be better to say 1.0000000 kilometer = 0.62136995 mile; that is, both sides should be given the same number of significant digits. Handbooks, however, never do this.

When finding the products of three or more approximate numbers or when squaring or cubing an approximate number, follow the rules for *multiplication.* If possible use the more accurate factors first. *Somewhat better results will be obtained if one more digit is retained in the partial products than will be retained in the final answer.* A similar rule may be used in division or an example in which both multiplication and division are needed.

In this vital matter of computing with approximate data in the elementary schools and the high schools *we need simple consistent rules that can be easily applied.* Statistical and other refinements are matters for the college and graduate school. The rules given in this article form a safe foundation on which the graduate school may build. It is true that when the rules given in this article are used, now and then a final digit that is not significant will be retained. This is not serious and will not conflict with work in science where it is common practice to retain a final figure that is on the "ragged edge."

Many of our modern textbooks are highly inconsistent in their treatment of computation with approximate data. Duane Roller says, "Most textbooks discuss the concept of significant figures (digits) but fail to take it into account in stating problems of a quantitative nature, thus making it almost impossible for the student to use the idea of significant figures in solving problems" [10]. A few modern texts give a fairly good treatment of computation with approximate data, but in succeeding chapters and in their answer books they fail to follow the rules that they have developed. In other texts the chapter treating approximate data is placed at the end of the text.

The data in any given problem in mathematics or science *should be consistent and should clearly indicate the accuracy desired in the answer.* No answer book should give, and no teacher should allow, more digits in a final answer in multiplication, division, or square root than there are in the least accurate item. The term *approximate computation* should not be used. The data in a problem *may be approximate* but *the computation is not.* Computation with approximate data is not rough, careless, or slipshod work. It is careful, intelligent computation that produces honest answers. The answers obtained are the best answers that can be secured from the given data.

The words *precise, accurate,* and *correct* should not be confused. *Precision* and *accuracy* are relative. The measurements 0.00064 inch and 2.43126 inch are equally precise (an equally small unit has been used), but the second measurement is far more accurate (it has more significant digits). If an answer is correct, no mistakes in computation have been made and finally it has been *correctly rounded.*

Computation with approximate numbers should be taught in grades seven, eight, and nine for the following reasons:

1. It is the only "real life" computation for practical or applied problems in which either measurements or any type or approximate numbers are part of the data.
2. It gives pupils a definite criterion for rounding answers in multiplication. That is, it gives the *why, when,* and *how* for rounding.
3. It gives pupils a criterion for telling at a glance how far to carry out any problem in division.
4. It gives pupils a criterion for determining the number of digits to retain when using numbers such as 3.14159, 0.785398, or 0.3183098; metric conversion or reduction factors, 1 kilometer = 0.6213699 mile; approximate values, such as 1.25 cubic feet = 1.00 bushel; specific gravities, such as 11.34 for lead; tangents; and the like.
5. It gives pupils a criterion for telling how far to carry out the answer to any example in square root.
6. It gives pupils a criterion for correctly using in problems data of differing degrees of accuracy.
7. It gives pupils a criterion for telling how far to carry

out the answer to an equation and how to check this answer.

8. It gives the pupils a criterion for telling how far to carry out the answer to any written problem in applied mathematics or science.

9. It prepares pupils for such approximate methods of computation as the use of logarithms, the slide rule, graphic solutions, square-root tables, compound-interest tables, and the like.

10. It enables pupils to use our old measuring units either alone or along with decimal factors and to retain the proper number of significant digits in the answer.

11. It eliminates ragged decimals in addition and subtraction.

12. It enables pupils to tell when they may annex zeros—only in division and roots—and how many zeros they may annex.

13. It gives pupils a criterion for working with fractional measurements and compound numbers. They will never make the mistake of assuming that 4 1/2 inches always equals 4 32/64 inches, and they will know that if they reduce 4 32/64 inches to 4 1/2 inches, they reduce the indicated accuracy of the measurement from three significant digits to one significant digit and also reduce the precision of the measurement. They will know that 4 inches has only one significant digit, whereas 4 0/64 inches has three.

14. It saves a considerable amount of time spent in useless calculation and gives better results. This is especially true when abridged multiplication or division is used.

15. It eliminates the incorrect rules and the large per cent of wrong answers found in many elementary texts. Pupils will not be taught rules, concepts, and techniques that are wrong and that must later be changed.

EXERCISES

(Answers Given in Parentheses)

1. Round to three significant digits: 87.46 (87.5); 92.54 (92.5); 3.1416 (3.14); 2,956.5 (2,960).

2. Round to four significant digits: 3.14159 (3.142); 0.78539 (0.7854); 218,352 (218,400); 218,252 (218,300).

3. Round to one significant digit: 3,956.5 (4,000); 59.86 (60).

4. Multiply and round to three significant digits: 8.64 × 7.26 (62.7); 14.36 × 18.29 (262.6); 42.9 × 86.5 (3,710, zero not significant); 28.56 × 8.23 (235.).

5. Multiply: 8.7 ft. × 3.1416 (8.7 × 3.14 = 27 ft.); 424.86 × 8.43 (424.9 × 8.43 = 3,580, zero not significant).

6. Divide: 57.6 ÷ 3.62 (15.9); 43.86 ÷ 18.23 (2.406); 29.8 ÷ 3.14159 (29.8 ÷ 3.142 = 9.48); 63.1 ÷ 89.73 (0.703).

7. Find the area of a trapezoid with $b_1 = 26.34$ ft., $b_2 = 18.96$ ft., and $a = 8.34$ ft. (189 ft.).

8. Find the area of a triangle with $b = 24.78$ ft. and $a = 19.26$ ft. (238.6 sq. ft.).

9. Give the value of π that should be used and the circumferences of the circles having the following diameters: 2.4 ft. (3.14, 7.5 ft.); 22.81 ft. (3.1416, 71.66 ft.); 23.6 in. (3.142, 74.2 in.); 183.59 ft. (3.14159, 576.76 ft.).

10. Find the square root of 81.00 (9.000); 6.2500 (2.5000); 3.000 (1.732); 64 (8.0).

11. What is the volume of a conical pile 32.76 ft. in diameter and 4.941 ft. high? (Solution: $V = 1/3 \times 3.1416 \times (16.38)^2 \times 4.941 = 1{,}388$ cu. ft.)

12. The side of an equilateral triangle is 12.00 ft. What is its area? $A = S^2/4\sqrt{3}$. (Solution: $(12.00)^2 = 144.0$. $144.0 \times 1/4 \times 1.7321. = 62.36$. Note: Since 12.00 has four significant digits, it is necessary to retain five figures in $\sqrt{3}$.)

13. Multiply 437.64 ft. by 0.3241 and add 164.3 ft. (437.64 × 0.3241 = 141.839124). Round this to 141.8 and add (164.3 + 141.8 = 306.1 ft.).

14. Find the cube root of 498.0 (7.926). Find the cube root of 493.0 (7.8998 = 7.900, zeros significant).

15. Find the number of significant digits in the following: 4° (1); 4° 0″ (5, since it is 14,400″); 9 ft. (1); 9 ft. 0/8 in. (3, since it is 864/8 in.); 42° 7′ 6″ (6); 4 yd. 2 ft. 6 1/8 in. (4); 124.70 ft. (5); 124 ft. 8 3/8 in. (5).

Do you see why practical people prefer decimal measures? They have so many advantages that scientists and others have changed to the metric system or have divided our old units decimally. So divided, the old units have many advantages of the metric system but lack the relationships so valuable for scientific work. (Note that 1/8 inch equals approximately 0.01 foot.)

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The Metric System in Science Education

PHILIP G. JOHNSON

THERE is wide variation in the stress given to the metric system in the teaching of science at secondary school levels. In many general science and biology classes very little attention is given to such instruction, whereas in some chemistry and physics classes there will be substantial amounts of measurements, and almost all of them will be in metric units with decimal fractions. There have been some evidences of change during the war years from general exercises in measurement to the applications of measurements to actual materials, such as specifications of an engine [4].[1] Such evidence is too limited to indicate a trend in teaching practice. There is a need for some careful research concerning status, trends, and possibilities in the use of the metric system and decimal fractions in science instruction.

If we were to ask science teachers to state whether or not they taught the metric system, I am quite certain that the great majority would respond affirmatively. Certainly the senior high school teachers of physics and chemistry would state an emphatic, "Yes." On further questioning, I think that science teachers at secondary school levels would admit using the English system in most illustrations, but again many physics and chemistry teachers would probably hesitate to give the impression that they used the English system very much either in illustrations or problems. General science and biology teachers would be less certain that they give stress to the metric system and decimal fractions.

In his study *Investigations of Vocabulary in Textbooks of Science for Secondary Schools* [3], Curtis included the following measurement words for general science: *centigrade, foot-pound, horsepower, kilowatt-hour, watt, ampere*, and *ohm*. There were no measurement words in the lists for biology, but the chemistry lists included: *centigrade, liter, centimeter, gram, Fahrenheit, ounce*, and *micron*. Authors and certain professors of chemistry suggested in addition the following: *angstrom unit, kilogram,*

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[1] Numbers in brackets refer to the References at the end of this article.

Type of Unit	*English Unit*	*Thousandth in Which Commonest*	*Metric Unit*	*Thousandth in Which Commonest* *
Time	Second	1	Second	1
Weight	Dram	10	Gram	12
	Ounce	3	Centigram	18
	Pound	1	Kilogram	10
Volume	Pint	4	Liter	14
	Quart	3		
Length	Inch	1	Centimeter	9
	Foot	1	Meter	4
	Yard	1	Decameter	20 plus
	Fathom	6		
	Rod	2		
	Mile	1	Kilometer	7
	Furlong	12		
Energy	Horsepower	12	Kilowatt	19
	British thermal unit	20 plus	Watt	10
			Calorie	9
Temperature	Fahrenheit	9	Centigrade	13

* For instance the word *second* is among the first thousand of the most commonly used terms, whereas the word *gram* is encountered in the twelfth thousand or is among the 12,000 most widely used words.

milliliter, *millimeter*, and *meter*. The study did not include a word list for physics.

When we examine a general listing of words [6] as encountered in reading 10,000,000 words from materials considered suitable and characteristic of what high school students read, we find that among the first 1,000 most commonly used words only six deal with measurement. These are: *foot*, *inch*, *mile*, *pound*, *second*, and *yard*. It is necessary to consider the 4,000 most commonly used words before a distinctly metric term will be encountered. This term is *meter*. The table given above shows the frequency of occurrence of certain words and therefore gives an index to their general importance, based on how often some selected measurement terms are encountered in the reading material of high school students.

The table indicates that, as teachers, we have adjusted our teaching very well to the use of measurement terms as found in general reading. The incriminating questions are: Have we done, and are we doing, enough to encourage an accelerated rate of acceptance of the metric system, which we feel is the only truly scientific system? Have we been, and are we now, sufficiently direct and clear in our teaching to prepare the way for the abandonment of a system which scientists have long since eliminated from their work? When *fathom* is more widely used than *kilometer*, and *dram* is more often encountered in general reading than *liter*, teachers of twenty to forty years ago seem to have been rather lax in laying a foundation for the general use of the metric system by their future writers. Are we doing any better today?

Since general science is constant in most secondary schools, we find in this course our most favorable opportunity to help our youth and future adults to understand the advantages of the metric system. Only a minority of these same students will take chemistry or physics courses, in which the system will again be given stress by science teachers. We will have to teach general science in such ways that the metric system will come to be known and understood through its utilization by students and teachers if we desire to reach all the students. It should be emphasized that our instruction should concern not so much the metric system as the actual use of the metric system. We can help students to understand that the metric system is easily used and globally understood.

Many science teachers will argue that such teaching would be largely useless and impractical because the metric system is seldom encountered in everyday life. They will contend that most of the students will not become scientists and that those who do so can learn the system later. In order to sense the possible significance of the metric system in the lives of their present general science students, science teachers will have to consider the needs of pupils as citizens of a world which operates more and more under the metric system. There is a need for experimentation in the area of metric instruction. Through a pooling of experiences a summary of tested practices could be assembled for the guidance of general science teachers who wish to aid students in developing an understanding of the metric system.

Biology represents the second-best opportunity to encourage our future adults in developing a sympathetic appreciation of the metric system. In 1933-1934 more than 53 per cent of the potential registrants were taking the subject. When botany and zoology were included, the percentage rose above 59 [7]. What are biological science teachers doing about the metric system? Here again we must confess that little or no information is available. Certainly there are many opportunities to stress the use of a scientific system of measurements. Among these may be mentioned the descriptions of specimens, the energy equivalents of various foods, the temperature scales, the micron and millimicron as units for measuring and describing microscopic forms, blood counts, blood pressure, formulae for nutrient solutions used for hydroponics, composition of patent medicines, prescriptions, records for track and field events, solution strengths and dilutions, and a large number of related topics. What biology teachers have done with these opportunities should be studied and reported so that the best practices may be made more generally known.

By the time pupils are sufficiently advanced for studies at the eleventh and twelfth grades, many will have dropped out of school, and the special values of chemistry and physics will be unavailable to them. For this reason the postponement of emphasis on the metric system until pupils have reached the senior high school will greatly reduce the effectiveness of metric instruction, even though the nature of the subject matter may on the whole be more appropriate to the development of more advanced measurement concepts by the students.

It seems rather trite to say that chemistry and physics instruction is naturally metric, yet many chemistry and physics teachers do very little about training students to use and appreciate the values of the system. Textbooks for physics usually give a portion of a chapter to measurements. There are discussions of common units, conversion factors or equivalents, verniers, micrometers, standards, constants, and the like. Some teachers [1] give as much as a week to the study of mensuration as such, but more time is unusual. It must be mentioned that much additional instruction is given in relation to the study of other topics so that at the end of the course the students may have arrived at a rather satisfactory understanding of metric measurements. Whether or not more attention should be given to direct instruction for understanding of the metric system is not known, but there appears to be a tendency to minimize the direct instruction and to give the instruction as the need is met in the study of other phases of the course. The particular value of direct instruction lies in the fact that it can be well organized so as to form a progressive development. A view of the entire system can be conveyed. Students can be taught to read scales of various types and to express their findings in numbers as well as units. The lack of interest which is encountered may be due to the practice of teaching mensuration as an end in itself rather than as a means to an end. Teachers have had students measure wooden blocks, sheets of paper, and metal cylinders when they might have had them measure the specifications of an engine, such as bore, stroke, displacement, crankshaft throw, and the like [4]. If teachers were to set before students a number of items of interest to the students, there would be an incentive to determine the physical dimensions of the materials. Physics teachers may wish to improve the general effectiveness of their direct approaches by having students measure something which they would like to examine. In this way teachers can develop plans for direct teaching of the metric system which will be both effective and interesting.

Teachers of chemistry have many opportunities to stress the metric system. Again, we must conclude from a survey of courses of study that the extent to which the metric system is used varies widely in classroom practice. Some chemistry teachers have no special time for laboratory work, and they may make their course largely a read-about-talk-about course. During World War II the chemistry teachers were urged to re-emphasize quantitative relationships and to extend their study of neutralization both from the classroom and laboratory standpoints [2]. While the metric system may be understood in general, it is in the development of quantitative relationships that the values of this system come to be appreciated. If the quantitative relationships are learned as a part of laboratory work with common materials, there is a likelihood that students will appreciate the values of the system. It would seem that high school chemistry teachers would have many special opportunities to develop the understanding of the metric system, especially as these relate to weight and volume relationships. There is very little in the professional literature to indicate that teachers have developed a clear and progressive plan for helping their students understand and use the metric system.

The need for greater technical proficiency on the part of young men who were inducted into military units or who were needed in strategic industries caused a greatly increased emphasis on an understanding of mensuration during the war period. Out of this need came suggestions [2] that schools put more stress on quantitative relationships. Suggestions included proposals for general science, biology, physics, and chemistry teachers; and several of the proposals had direct reference to the metric system. These suggestions were made the basis for more local suggestions, and a re-emphasis on mensuration and the metric system was urged upon science teachers.

Another means of improving instruction related to mensuration was to utilize films and other visual aids. An appreciation of the value of motion pictures in training workers resulted in the production of a number of titles, such as *The Steel Rule, The Micrometer, Fixed Gages, Verniers, Height Gages and Test Indicators, Precision Gage Blocks, Gage Blocks and Accessories, The Bevil Protractor, Measurement with Light Waves.* These were produced under the direction of the U. S. Office of Education [8] and represent films which are technically accurate, photographically good, and educationally sound. Together with an accompanying film strip and a teacher's manual they represent a potent means for carrying forward an aspect of science instruction which has been in need of expert visualization. Science and mathematics teachers should try these new educational tools and report their results to others.

It is possible that science teachers should give more careful thought to the development of carefully organized instructional materials relating to the use of the metric system. Teachers might well gather together suggestions for developing an understanding of and appreciation for the metric system. In such a series of suggestions they might well include the following: introductory approaches, illustrations from everyday life, possible experimental demonstrations, opportunities for individuals or groups of students to experiment, plans for homemade gadgets, useful library sources, desirable films, film slides, lantern slides, charts, and other visual aids, authoritative discussions of new or especially important phases, teaching and study outlines, project proposals for students, test materials, and other suggestions which would indicate in considerable detail just what a science teacher might do to develop interest in and guide efforts toward effective learning in relation to the metric system. When several teachers have attempted to prepare such learning guides, their guides might be compared, and a pooling of the better suggestions might lead to a resource unit which would be of great value to teachers all over the country. If anything like this has been done, there is no material readily available to reveal what was accomplished.

As has been mentioned before, there are numerous indirect methods for developing the metric system through the sciences. Some of these may involve the organization of new courses, such as one in laboratory techniques. Others may be limited to phases of other courses, such as is possible in several sections of general science, biology, chemistry, and physics. Instruction toward the same general objective may be made a part of unit courses or core courses. Again, a sharing of experiences should lead to procedures and techniques which are more generally effective than the casual plans which are in common use by science teachers.

In conclusion, it may be said that science teachers have not been very active proponents of the metric system. They have often been careless in their selection and use of methods for introducing and teaching the system. Many of them have depended upon the hope that students would learn the merits of the system when they studied the more exact sciences. Many opportunities for calling attention to the advantages of the system have been lost, because there has been a vagueness concerning the objectives to be attained. Pupils have often been bored by a presentation in science which overlooked previous instruction in mathematics [5]. On the whole, we have not been very scientific in our development of the metric system. It is highly desirable that we should study present-day needs and opportunities. We should counsel with teachers, scientists, and general workers. We should formulate plans which will make it possible for science teachers to encourage the advancement of science and the growth of international understanding through the more general use of the metric system. It is to be hoped that this Yearbook may be the beginning of careful planning and intelligent action on the part of all who are now active participants in the teaching profession.

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The Metric System:

A Teaching Unit for Junior High School

J. T. JOHNSON

Prerequisites

I. The fundamentals of decimals.
II. Approximate measurement.
  A. Measurement to nearest foot and nearest inch.
  B. Rounding off to nearest tenth, hundredth, and thousandth.
III. Knowledge of how to find areas of rectangles.
IV. Knowledge of how to do simple examples in percentage. (Cases I and II.)

Materials

I. Eight meter sticks. Two yardsticks.
II. Each student should have foot rule marked in millimeters (mm) and sixteenths of an inch.

Specific Objectives

I. Estimation of metric lengths—within 10 per cent error.

II. Actual measurement of objects in metric units—to nearest centimeter (cm).

  A. To find lengths and learn the relations between the different units of length.

  B. To find areas and learn the relations between the different units of area.

III. Comparative computation within the metric and English systems involving the above phases of measurement.

Brief History

Have you ever thought of how people lived before there were any measures? What was the first measuring instrument? Where did it come from? Who first used the yard? How did the meter come into use, and where and when? The story of measurement is a fascinating story and one which you ought to read. Some of the interesting things about how we got our yard and meter will be told here. If you are interested you can read more about it.[1]

Long, long ago, when man had no number system and used his fingers for counting, he also used parts of his body for measuring. His fingers, hands, arms, and feet were the most convenient for this. The first known measure was the cubit. It was the distance from the elbow to the end of the middle finger. The width of the hand was used for measuring heights. A horse was 14 hands high. Man used his feet in stepping off small distances. Our foot measure came from the length of the human foot. The step or pace used in longer distances is used today by Boy Scouts.

Other measures based on the human body were the ell, which was the length of the arm, and the fathom, which was the length of both arms outstretched from finger tip to finger tip.

The length of the arm, or the ell, was later called the yard. It was defined in England as the length of the arm of King Henry I, from the tip of his nose to the end of his fingers. The foot then became one-third of the yard.

These approximate measures were used in Europe for a long time, up to as late as 1790. At one time there were as many as 282 different lengths of the foot in Europe. Each little country and even city had its own foot measure. There was the Rhineland foot of 12.35 inches, the Roman foot of 11.67 inches, and the Amsterdam foot of 11.14 inches. You can imagine the confusion caused by having so many different lengths of foot measures.

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[1] *The Story of Weights and Measures.* The American Council on Education, Washington, D. C., 1932.

In 1790, because of this confusion, the King of France issued an invitation to the other countries to meet to discuss a new system of measurement. Delegates from the principal countries came to this convention and discussed and debated for a long time over the problem. They finally decided to use as the unit of length a part of the earth's circumference. To have it conveniently small, it had to be one ten-millionth part of the earth's quadrant, that is, of the distance from the equator to the North Pole. This length was to be called a meter (metre). In order to make the first exact meter, this ten-millionth part of the earth's quadrant had to be measured. The meridian, or line of circumference, passing through Paris was chosen, but not all of this quadrant could be measured, for much of it was over the water. A portion was selected between Dunkerque on the northern coast of France and Barcelona on the southern coast of Spain. Two French engineers, Delambre and Méchain, were chosen to do the surveying. They began this work in 1792 and finished in 1799. It was a long and arduous task, for it was during the time of the French Revolution, and the surveyors had much trouble with the people of the land in which they were surveying. It thus took seven years to make the first meter stick. It was made of platinum-iridium, and is now kept in an underground vault near Paris.

The meter sticks that we use have been made from copies of the original one just described. This is a meter stick. It is a little longer than the yard, as you see.

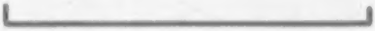
PRESENTATION

I. ESTIMATION OF METRIC LENGTHS

EXERCISE A

1. The first step in becoming familiar with the metric system is to become conscious of its units of length. You have all seen

the meter stick now and how it is divided. You may take out your metric ruler and study the markings on it. Try to visualize a line 10 cm long, then hide your ruler and draw from memory on your paper a line 10 cm long. Mark the ends of it like this so that it will be easy to measure:



2. Exchange papers (odd rows with even rows) and measure with rulers and mark the proper length on your neighbor's paper, and return papers to owners. Did any of you get a line exactly or almost exactly 10 cm long? Your error should not be more than 10 per cent of 10 cm. How many were less than 1 cm off? The rest of you need more practice.

3. Let us try this again. Put away your paper and on a fresh paper draw from estimate a line 10 cm long.

4. Exchange and measure and mark as before.

5. How many improved upon your first estimate?

6. How many were less than 10 per cent off?

7. Next visualize a centimeter. The thickness of a slice of bread is about 1 cm. It is a little less than 1/2 in.

8. Draw from memory a line on your paper which you think is 1 cm long.

9. Exchange papers again and measure and mark as before and return papers to owners.

10. What is 10 per cent of 1 cm? Did anyone have a line less than 1 mm off? One millimeter is difficult to measure. Mark the ends of your centimeter line and it will be easier to measure.

11. Did anyone get better results this time than on the 10-cm line? Do you think you can do better a second time?

EXERCISE B. AN ESTIMATE CONTEST BY ROWS

1. Now we shall find out how good you are at estimating long lines. It is the whole meter this time. It is a little longer than the yard as you see. You cannot draw it on your paper, so we shall do this by rows on the blackboard. Take a good look at the meter stick. Each one in Row 1 may pass to the board and draw from estimate a line 1 meter long.

2. Those in Row 2, each with a meter stick, may pass to the

(drawn estimate of meter) error = 9 cm

board and measure and mark and designate error as shown above. [Note: If there is only one meter stick, the teacher and a student may do the measuring.]

3. If we are trying to find out which row has the best estimate, how are we going to find out how well the whole row did?

4. Find the average of the errors made by Row 1.

5. Row 8 (or 6) may next pass to the board and draw from estimate a line a meter long.

6. Row 7 (or 5) may go to board and measure and find error as before.

7. Find the average error of Row 8 (or 6).

8. The remaining rows may continue with the exercise until the average error of each row has been computed.

9. The row having the best estimate, that is, lowest average error, wins the contest. The individual student who had the best estimate among all the rows should receive honorable mention.

10. All of you should now have a pretty good idea of the length of a millimeter, a centimeter, and a meter. You should have a better understanding of average and per cent of error than before. We shall next do some actual measuring and computing in the metric system itself.

II. MEASUREMENT IN METRIC UNITS

A. MEASUREMENT TO FIND LENGTHS

As an exercise to give you further acquaintaince with the meter (m), you are asked to measure the length of your schoolroom with a meter stick. Use the zero end of the meter stick as the forward end when you measure and count the number of whole meters until there is less than a whole meter left. Mark the spot where the last whole meter was counted and measure from the corner to that spot and then right there read your answer from the meter stick in meters and nearest centimeter. You may watch as I measure the width of the room.

[Note: The instructor should show how to use and read the meter stick in measuring the width of the room before the class. Several volunteers may then measure the length, working in pairs, one to handle the meter stick and the other to mark and check on the counting. The instructor should know previously the length of room correct to nearest centimeter.]

The answer may be written as one number with one name; for example, the result may be 7.84 m. When you get your answer, announce it and write it on the board. Another pair may volunteer to measure length to check on the first measure.

You may now copy the dimensions of the floor of this room in your notebooks for future reference. Write them in meters and hundredths. Measure next the length and width of your schoolroom with a yardstick in the same manner and write the result in feet and inches. Did you notice any difference in the measuring or the writing of your results? What caused the difference? Keep these dimensions also for future use.

Measure with the meter stick to the nearest centimeter [different students may be called upon]:

1. The length of a table top.
2. The width of a table top.
3. The height of a table.
4. The width of the blackboard.
5. The height of chalk ledge from floor.
6. The width of a door.
7. Measure your height in centimeters. [Note: If there is only one meter stick in the room, a pupil may place the following markings on a door post: 1 m, 110 cm, 120, 130, 140, 150, 160, 170, 180 cm. Then each pupil as he steps up to be measured will need only his own ruler to measure his height above any of these marks.]

Record your own heights in centimeters for future use.

Learn this easy table of lengths in the metric system:

10 millimeters (mm) = 1 centimeter (cm)
100 centimeters (cm) = 1 meter (m)
1,000 meters (m) = 1 kilometer (km)

The above easy relations are all that you need to know in the metric system of lengths.

8. Using the above table, change

a. 3 cm to mm.
b. 6 m to cm.
c. 12 km to m, to cm, to mm.
d. 20 mm to cm.
e. 300 mm to cm.
f. 4,000 mm to cm, to m.
g. 5,000,000 mm to cm, to m, to km.
h. 12.345 km to m, to cm, to mm (same as *c* above).
i. 6,792,576 mm to cm, to m, to km (see *g* above).

9. From the interrelations among millimeters, centimeters, meters, and kilometers now known, fill in the blanks below with proper numbers:

	mm	*cm*	*m*	*km*
a.	60	——	——	——
b.	——	40	——	——
c.	——	——	3	——
d.	16	——	——	——
e.	——	——	——	.750
f.	4,692	——	——	——
g.	——	5.6	——	——
h.	——	——	7.13	——
i.	——	——	——	4.6
j.	——	——	10.695	——

B. MEASUREMENT TO FIND AREAS

1. How do you find the area of a rectangle from its dimensions? The floor of a classroom is 8.1 m by 7.7 m. What is its area? To find its area multiply 8.1, the number of meters in length, by 7.7, the number of meters in width, and obtain the answer in square meters. Then round your product to the nearest whole square meter.

2. Use the dimensions for length and width of *your* schoolroom floor and find the area the same way. Measure to the nearest tenth of a meter. Round your product to the nearest tenth of a whole square meter.

3. Next, find the area of the floor in square feet. Either use feet and fractions of a foot or change all dimensions to inches first.

4. If you use feet and fractions for dimensions, what will be the name of your answer?

5. If you use inches in each dimension, what will be the name of the area?

6. Which method seemed to you to be the easier, using feet and inches or meters and centimeters? Can you tell why?

7. You will remember from your earlier work in grade 7 in areas, that the answers were expressed in square units, as square inches, square feet, and square yards. As you are now working in metric units, what will be the name of the square units in the areas?

8. Here is a square centimeter. Note that it is 1 cm in each dimension.

9. Here [page 275] is a square, 10 cm on a side. How many square centimeters are there in its area?

10. Let us find how many square centimeters there are in a square meter. You cannot draw a square meter on your paper, but you can do so on the board. Who can draw a square meter on the board using the meter stick?

11. How could we find how many square centimeters there are in this square meter without drawing them? It would take too long to draw and count them.

12. How many square centimeters are there in 2 sq. m? in 4 sq. m? in 24 sq. m?

13. In changing square meters to square centimeters, then, you multiply by 10,000, and that is easily done by simply adding four zeros or moving the decimal point four places to the right.

a. Change 36 sq. m to sq. cm.
b. 21.4 sq. m equal ? sq. cm.
c. 6.49 sq. m equal ? sq. cm.
d. 5.345 sq. m equal ? sq. cm.
e. 3.4096 sq. m equal ? sq. cm.
f. .6095 sq. m equals ? sq. cm.

14. In changing the reverse way, square centimeters to square meters, you would, of course, divide by 10,000. In dividing by 10,000 you do the reverse of multiplying by 10,000; that is, you cut off four zeros or move the decimal point to the left four places.

a. How many sq. m are there in 60,000 sq. cm?
b. Change 40,000 sq. cm to sq. m.
c. 63,000 sq. cm = ? sq. m.
d. 45,300 sq. cm = ? sq. m.
e. 34,690 sq. cm = ? sq. m.
f. 45,965 sq. cm = ? sq. m.
g. 3,496 sq. cm = ? sq. m.
h. 892 sq. cm = ? sq. m.
i. 25 sq. cm = ? sq. m.
j. 3 sq. cm = ? sq. m.

15. Fill in the blanks with proper numbers:

	sq. m	*sq. cm*
a.	——	4,561
b.	3	——
c.	——	32,490
d.	45.69	——
e.	——	606
f.	.063	——
g.	.0005	——

III. COMPARATIVE MEASUREMENT AND COMPUTATION IN METRIC AND ENGLISH UNITS

1. Measure the length and width of one blackboard in centimeters and find the area in square centimeters. Write the answer in square meters.[2]

2. Measure the length and width of the same board in feet and inches and find the area in square feet.[2]

3. Measure the length and width of one window pane and find its area in square centimeters.

4. Find the area of the same pane in square inches.

5. Compute the area of all the window panes in the room in square centimeters. Round the answer to the nearest tenth of a square meter.

6. Do the same in square inches. Write the answer in square feet and square inches.

7. Which problem seemed easier to you, No. 5 or No. 6?

8. Where and how was it easier?

9. The total area of the window space in a schoolroom should be one-sixth of the area of the floor space. Find what part the total area of the window space is of the floor space in your schoolroom.

10. Check this by doing the same using areas in square feet and square inches. (There are 144 sq. in. in 1 sq. ft.)

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[2] In cases of this kind where one object is to be measured by the whole class, it is better to let two reliable volunteers do the measuring before the class as a matter of expediency.

PRACTICE EXERCISES

EXERCISE I

1. Write the table of length for the metric system.

? mm = 1 cm ? cm = 1 m ? m = 1 km

2. Without a ruler draw a line by estimate 6 cm long on your paper.

3. Measure the width of a board in the floor to nearest centimeter.

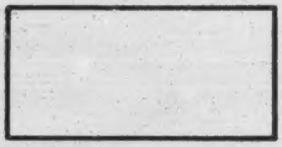
4. Estimate to nearest centimeter the length of your teacher's desk.

5. Express .000675 km in meters, in centimeters, in millimeters.

6. Write 750 mm in centimeters, in meters, in kilometers.

7. Write 46,798 sq. cm in square meters and then round to the nearest tenth of a square meter.

8. Find the area of this rectangle in square centimeters.



9. Write the answer in square millimeters and then check by measuring in millimeters and finding the area.

10. Draw a rectangle that will contain 12 sq. cm.

EXERCISE II

1. Write the table of length for the metric system.

2. By estimation without ruler draw a line on your paper 8 cm long.

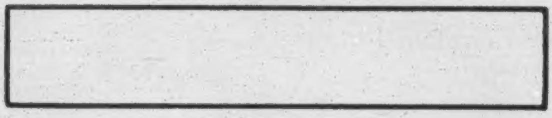
3. Measure to the nearest centimeter the width of this paper.

4. Estimate to nearest meter the height of your room.

5. Write 6 km in meters and then in centimeters, and then in millimeters.

6. Change 469,560 sq. m to square centimeters.

7. Write .7896 sq. m in square centimeters.



8. Measure the rectangle above in millimeters and find the area in square millimeters, then round the answer to square centimeters.

9. Check your answer in No. 8 by measuring directly in centimeters and finding the area in square centimeters.

10. Draw a rectangle so that its area will be 16 sq. cm.

Tests

TEST I

1. Write the table for length in the metric system.

2. Measure the length of the outside cover of your book to the nearest centimeter.

3. How many millimeters are there in 6.7 cm?

4. Write 67.95 m in centimeters.

5. Change 410 m to kilometers.

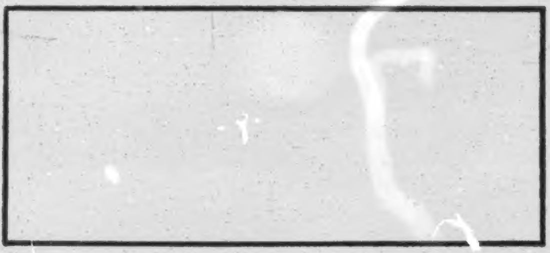
6. Change 5,945 sq. cm to square meters.

7. Write 16.005 sq. m in square centimeters.

8. The floor of a schoolroom measures 8.17 m by 7.25 m. Find the area and round to nearest tenth of a square meter.

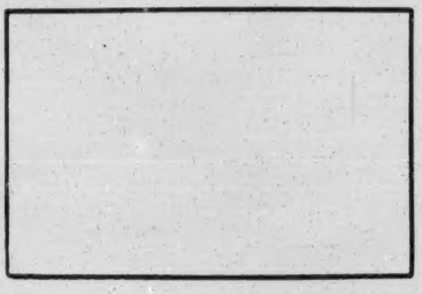
9. Estimate the height of the top of the blackboard from the floor in centimeters. (Allow for error of 10 per cent or less.)

10. Find the area in square centimeters of the figure below. Write the answer also in square millimeters.



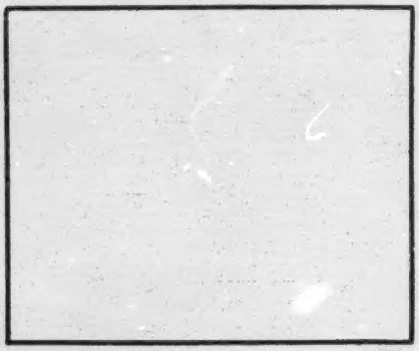
TEST II

1. Write the metric system table for length.
2. Measure the width of the outside cover of your textbook to the nearest centimeter. (Measure to the groove.)
3. Change 495 mm to centimeters.
4. Write 6.9 cm in meters.
5. Change 6.31 km to meters.
6. Write .3456 sq. m in square centimeters.
7. Change 39,458 sq. cm to square meters.
8. A floor measures 6.8 m by 5.6 m. What is its area to the nearest whole square meter?
9. Estimate the height of a bookcase or similar object in your room in centimeters. (Allow for 10 per cent error or less.)
10. Find the area of the rectangle below in square centimeters and express the answer in square millimeters.



TEST III

1. Write the table for length in the metric system.
2. Measure the length of a page of your textbook to the nearest centimeter.
3. How many centimeters are there in 4.6 mm?
4. Change 878 cm to meters.
5. How many kilometers are there in 350 m?
6. Write 46,945 sq. cm in square meters.
7. Change 7.8969 sq. m to square centimeters.
8. A table top measures 1.5 m by 2.8 m. Find the area and round the answer to the nearest tenth square meter.
9. Estimate in centimeters the height of a door in your room. (Allow for 10 per cent error or less.)



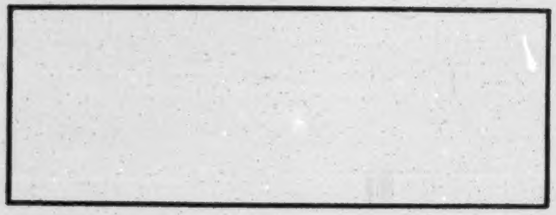
10. Find the area of the rectangle above in square centimeters.

ENRICHMENT EXERCISES

SET B

(*For those who have mastered the requirement in one or more of the tests.*)

1. Measure the figure below in metric units and express the area in square millimeters.



2. Express the area in square centimeters.
3. Express the area in square meters.
4. Express the area in square kilometers.
5. What decimal part of a square meter is the area of the above rectangle?
6. Look at your foot ruler, which is also marked in millimeters. Express its length in centimeters and tenths of centimeters.
7. Express the length of the ruler in millimeters.
8. Estimate the height of your teacher in centimeters.

9. Change 67,954,321 mm to meters.
10. Change 67,954,321 sq. mm to square meters.

SET A

(For the faster students who have mastered the minimum requirement in the tests and have done what they could in Set B.)

The army uses guns calibrated in metric dimensions. By the use of two rulers side by side find how many inches (to nearest eighth) the following gun calibers are:

1. 75-mm anti-aircraft gun.
2. 88-mm German tank gun.
3. 90-mm German tank gun.
4. 105-mm howitzer.
5. 155-mm howitzer.

If you are an A student, you should be able to do some fine measuring.

6. Find the difference in millimeters between the diameters of a penny and a dime.

7. How are you on large numbers? Measure the length of a dollar bill. Use the nearest whole centimeter, since a new bill may be a little longer than the used one you are measuring.

8. How many of these bills would it take, laid end to end, to reach around the earth at the equator? (You know from the history section in this unit that 1 m is one ten-millionth part of the earth's quadrant—a quarter of the earth's circumference—and you can change the length of a dollar bill from centimeters to meters.)

9. If the cost of World War II was $300,000,000,000, how many times would that amount go around the earth in dollar bills laid end to end?

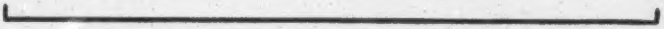
10. If the $1 bills in No. 8 had been $1,000 bills (same length) would they have paid for the war? If not, would they have paid for one-fifth of it?

FINAL PRACTICE EXERCISES FOR MAINTENANCE

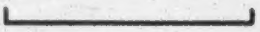
As an outcome and permanent achievement from this unit, you should be able to do one of the following two exercises without a mistake.

EXERCISE I

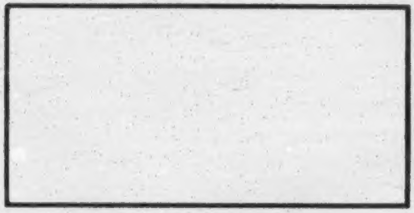
1. Estimate the line below to the nearest centimeter with 20 per cent error or less.



2. Measure this line to the nearest millimeter.



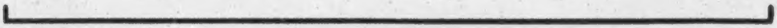
3. Express the length of the line in No. 2 in centimeters.
4. Express the length of the same line in meters.
5. Express the length of the same line in kilometers.
6. Change 57.94 m to millimeters.
7. Find the area of the figure below and express it in square centimeters.



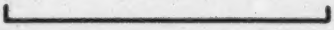
8. Express the same area in square millimeters.
9. Round 6.795 sq. m to the nearest tenth of a square meter.
10. Write the table of length in the metric system.

EXERCISE II

1. Write the table for linear measure in metric units.
2. Estimate the length of this line to the nearest centimeter.

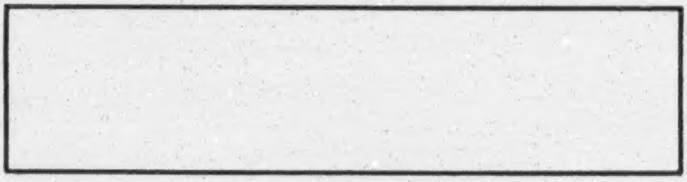


3. Measure the line below to the nearest millimeter.



4. Express the length of the line in No. 3 in centimeters.
5. Express the length of the same line in meters.

6. Write its length in kilometers.
7. Find the area of the rectangle below in square centimeters.



8. Find the area of the same rectangle in square millimeters.
9. Round to the nearest whole meter: 16.5795 m.
10. Change 5,794 mm to meters.

Teaching the Metric System to Prospective Teachers

L. H. WHITCRAFT

No PERSON questions the importance of being familiar with the common units of measurement or of teaching such units to the children in the public and private schools of the United States, since one or more of these units have some part in the daily life of practically everyone. Units of time, rate, distance, weights, capacity, area, volume, and money are included in the list of units that are most used in any system of measurement. They are the units that are supposedly familiar to the general public when given in the system known as the English system of measurement. They are not generally familiar units when given in the system known as the metric system.

The metric system is important, since it is the adopted system of measurement for all countries of the world except the British Empire and the United States of America. More than 75 per cent of the world population use it as the standard of their measurements. Its units are simple ones, and they are clearly defined. They are designed to meet all needs for measuring, recording, and calculating physical quantities with convenience, simplicity, and consistency. The ratio between any two of its consecutive units is 10 or some multiple of 10.

BRIEF HISTORY AND GROWTH

Although the history of the metric system is given in detail in another section of this book, it will be to the reader's advantage to have some of it briefly reviewed here.

The early units of measure were rather crude and indefinite. This may well be understood when one recalls that those units of measure represented the length or width of various parts of the human body. To illustrate, the width of the finger, the breadth of the hand, the length of the foot, the length of the forearm, and the length of a step were widely used as standards of measurement. The great variation in the size of these units for different individuals within a community was quite confusing and very unsatisfactory. Communities, therefore, set up standards for themselves by defining the units as those belonging to a particular individual within the community, usually the leader or king.

At the time when trade between communities was undertaken, there were many of these independent systems of measurement. We are told that in the year 1790 there were more than two hundred different lengths for the linear unit, "the foot," on the continent of Europe. Such a large number of different standards for the same unit made commerce between localities or nations very difficult, so difficult that finally attention was given to finding an object in nature which could be used as a standard, one that would be definite, convenient, and unchangeable.

In 1790 the National Assembly of France requested Louis XVI to open correspondence relative to the question of measurement with the other powers of western Europe. The outcome of this correspondence was the international commission which met soon after in Paris. This commission recommended that the standard unit of linear measure be made a convenient part of the earth's circumference. This convenient part was intended to be a length equal to one ten-millionth part of the distance from the equator to the Pole. To determine this length two engineers, Delambre and Méchain were appointed to make the survey. Approximately seven years were spent in making and checking the survey. This unit is now defined as the distance between two engraved lines on a bar of platinum-iridium alloy, approximately one ten-millionth part of a quadrant of a meridian. The standard meter stick is preserved in the archives of the International Metric Commission at Sèvres near Paris.

The unit of weight, the gram, was intended to be a mass of pure water, whose volume at 4° centigrade would be equivalent to a cube with its edge equal to 0.01 meter, or 1 centimeter. Since this unit is comparatively small, a larger unit, having a mass of 1,000 grams, or 1 kilogram, was set up as the standard unit of mass.

The unit of capacity, the liter, is defined as the volume of 1 kilogram of water at its greatest density.

All units are theoretically based on the meter, the unit of length, and the tables are built on the decimal plan. The three principal units are the meter, the liter, and the gram.

Length

10 millimeters (mm) = 1 centimeter (cm)
100 centimeters (cm) = 1 meter (m)
1,000 meters (m) = 1 kilometer (km)

Capacity

1,000 milliliters (ml) = 1 liter (l)

Weight

1,000 grams (g) = 1 kilogram (kg)
1,000 kilograms (kg) = 1 metric ton (t)

Since the establishment of the metric system, its usage has spread until at present more than 75 per cent of the world population and fifty-five of fifty-seven countries have it as their standard of measurement. Between 1800 and 1860 very few countries adopted it as their standard, in fact, not more than seven. For the most part they were the countries that border France. From 1860 to 1900, thirty-three additional countries made it their standard of measurement. Since 1900 fifteen of the remaining countries have adopted it, leaving the British Empire and the United States alone having systems other than the metric in common usage.

TRENDS TOWARD THE ADOPTION OF THE METRIC SYSTEM IN THE UNITED STATES

A glance at the history of the United States relative to standard units of measure gives evidence that it has moved in the direction of adopting the metric system. From the very beginning as a nation this country has been interested in uniform units of measure. George Washington's first message to Congress, in 1790, contained the following statement: "Uniformity in the currency, weights, and measures of the United States is an object of great importance and will, I am persuaded, be duly attended to."[1]

Congress in the same year responded by requesting Thomas Jefferson, Secretary of State, to do something toward making standards of measure uniform. Jefferson, therefore, submitted plans, one of which was to reduce every branch of the principal affairs of life within the arithmetic of every man who can multiply and divide plain numbers.

Washington's second message to Congress contained a statement relative to the need for uniform standards. No legislation, however, followed.

In 1821, John Quincy Adams, Secretary of State, reported that he would consult with foreign nations for the future and ultimate establishment of universal and permanent uniformity in weights and measures; yet no action followed. By this time there was some evidence that the people of the United States were dissatisfied with the confusion that resulted in the use of English units of measure at home and metric units of measure abroad. This dissatisfaction brought an extensive report by Congress.

Congress, in July, 1866, passed the following act, which authorized the use of the metric system of weights and measures:[2]

> Be it enacted by the Senate and House of Representatives of the United States in Congress assembled, That from and after the passage of this act it shall be lawful throughout the United States of America to employ the weights and measures of the metric system, and no contract or dealings, or pleadings in any court, shall be deemed invalid or liable to objection because the weights or measures expressed or referred to therein are weights and measures of the metric system.

In 1875 the United States and sixteen other countries sent representatives to a metric convention held in Paris. The purpose of this convention was to establish and maintain a permanent scientific International Bureau of Weights and Measures at Sèvres near Paris. From this bureau the United States received her National Prototype Meter and Kilogram, which are duplicates of the standard meter and kilogram kept in France. The prototypes are kept in a subterranean vault of the National Bureau of Standards at Washington, D. C.

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[1] *The Mathematics Teacher,* Vol. XXII, November, 1929, p. 380.
[2] *Ibid.*, p. 380.

In 1893 the meter and the kilogram were made standard units of measure in the United States. The yard was defined as 3,600/3,937 of the meter, and the pound avoirdupois as 1/2.2046223 kilogram. The following year, 1894, the War Department adopted the metric system for medical work, and during that same year it was made the basis for all electrical measurements. Eight years later, in 1902, it was adopted by the United States Health Department. In 1932 the Amateur Athletic Union adopted the metric system.

In 1926 a bill was introduced in Congress to change from the English system of measures to the metric system, but it failed to pass by a few votes. This bill proposed ten years for making the change over to metric units. Since that time there have been no further attempts by Congress to adopt the metric system.

A number of organizations have rather recently passed resolutions favorable to the metric system. At the annual convention of the General Federation of Women's Clubs, meeting in St. Louis in April, 1944, a resolution was introduced and adopted unanimously by the delegates to endorse legislation in Congress for the nationwide adoption of the metric system of weights and measures. This body represents 16,500 women's clubs and 2,500,000 individual members. The Central Association of Science and Mathematics Teachers at its annual meeting, November, 1944, in Chicago went on record as favoring some form of legislation for immediate metric usage in those lines most feasible for metric adoption. During this same year the Council on Pharmacy and Chemistry of the American Medical Association announced that it would use metric units only in publications for which it is responsible.

The Kiwanis Club and the Rotary Club of Mankato, Minnesota, and the Lions Club of New Canaan, Connecticut, have drawn up and passed metric resolutions favoring Congressional action for metric usage. The Mankato Rotary Club has invited consideration by all Rotary Clubs in the United States to pass similar resolutions. The Lions Club above mentioned has approached the Lions International Committee, who have spoken in favor of the metric system.

In 1936 J. T. Johnson, President of the Metric Association, Chicago, sought additional information relative to public opinion on the use of metric units. He mailed a questionnaire to some 650 individuals, including manufacturers, engineers, doctors, and educators. From the returns of his questionnaire he found that 80 per cent of those answering believed that it would be of ultimate advantage to the United States to use metric weights and measures, that as many as 75 per cent believed that the adjustment from English to metric units could be made in a period of ten years without any serious inconvenience, and that of those favoring a change to metric units 74 per cent believed one of the best ways to effect the change would be through government legislation, 94 per cent through education and use in the schools, and as many as 90 per cent through both government legislation and use in the schools.

From the preceding statements one realizes that the metric system is gaining ground in the United States. It has gained in number of individuals friendly to it and in the number using it. The trend then is toward wider use pointing toward final adoption of the system.

METRIC UNITS TAUGHT IN ELEMENTARY SCHOOL

The children in the elementary school have had an opportunity to learn something of the metric system. A survey of ten series of widely used arithmetics, published before 1940, revealed that practically all the material having to do with metric units was included in the texts for grades seven and eight. Two series, however, included certain metric units in grade six. Eighth grade texts examined contained slightly more than five pages of material on the metric system. Considerable attention was given to converting units of the English system to those of the metric and those of the metric into English units, with less attention to measuring and computing with metric units.

WHAT FIFTY-FIVE COLLEGE STUDENTS KNEW ABOUT THE METRIC SYSTEM

During the fall and spring quarters, 1945-1946, the writer obtained from fifty-five college students in general mathematics some information relative to their knowledge of the metric system. The larger number of these students were preparing to teach elementary grades. Seven of the group were returned veterans, and five other students were taking courses for the preparation of nurses. No attempt was made to compare the three groups of students. The list of questions submitted to them was:

1. What is the metric system?
2. What per cent of the nations of the world use it as their standard of measurement?
3. What group or groups of people in the United States use this system widely?
4. With what units of the metric system are you familiar?
5. How did you come to know these units?
6. To what extent have you studied the metric system?
7. Express in metric units (*a*) your height, (*b*) your weight.

The answers to the above questions were somewhat revealing. Approximately one out of three gave a good definition of the metric system. Seven of the fifty-five students were unable to define it.

Question 2 was not a very good question. It was too definite; yet three students came within 5 per cent of it. Five of the group did not list the per cent; instead, they made the statement that all countries except the United States and Great Britain had adopted it. Another student stated that most all countries use it, while one other said that all countries except the United States use it.

The various groups mentioned in answer to Question 3, with the number of students listing the group shown in the parentheses, were:

Scientists (40)
Everyone (6)
Engineers (3)
Surveyors (3)
Doctors (2)

Traders, buyers, businessmen (2)
Contractors (2)
Bureau of Standards (1)
Mathematicians (1)
Laboratory technicians (2)
Assessors (1)

The metric units with which they claimed to be familiar were:

Units of Length

Millimeter (21)
Centimeter (24)
Meter (33)
Decameter (4)
Decimeter (12)
Hectometer (2)
Kilometer (10)

Units of Capacity

Milliliter (2)
Liter (15)

Units of Weight

Milligram (6)
Centigram (1)
Decigram (2)
Gram (21)
Kilogram (12)

Twelve of the group stated that they were not familiar with any of the metric units.

The manner in which these units were learned was reported as follows:

Study of science (39)
Public school (13)
Mathematics classes (5)
Practical experience (4)
Read about them (4)
Medical school (1)
Dental work (navy) (1)

The approximate amount of time spent in study of metric system as stated by these students was:

Very little (20)
Few days (6)
Not at all (4)
Occasional remarks (3)
Just enough to do science (3)
One year in chemistry (3)
Large extent in science (1)
Enough to recognize units but not to use them (1)
Just mentioned it (1)
Just compared meter stick with yardstick (1)

Twenty-eight of the students were asked to express their heights and weights in metric units. Six of them gave their heights in English units and then converted them into metric units. Eighteen made no attempt to answer, while four gave their heights as 6.2 decimeters, less than 1.5 meters, 2 meters, and 6,600 meters respectively. Just three of the twenty-eight students gave their weights in metric units. Two of the three expressed their weights in pounds and then multiplied that by 2.2, while the third gave 140 liters as her weight.

When the students were asked to go to the board and draw, freehand, a line one meter long they were unable to do it very accurately; yet the relative error in their work was approximately the same as when they drew, freehand, a line 1 yard long. They had not had much practice in this type of work and were not good at estimating lengths or distances.

COMPARISON OF THE METRIC SYSTEM WITH THE ENGLISH SYSTEM

One of the first differences an individual finds when comparing the metric system with the English system of weights and measures is in the definition of the units. The basic metric unit, the meter, is defined as a part of a natural unit, either the quadrant of a meridian or the spectrum of a cadmium ray; therefore it could be determined again if all measuring units were destroyed. From this unit all other units of the metric system could be reestablished. In the English system of measurement this would be practically impossible. For this reason there appears to be a feeling of security in the use of metric units not found in the use of English units.

The second difference noted in the two systems is the relation between consecutive units. The metric system has the decimal division within its units, a fact which makes for economy in learning as well as in computation. Changing from one unit to any other unit in the metric system is really a matter of moving the decimal point to the right or left, a process which involves multiplication or division by 10 or some power of 10. One illustration will be sufficient to convince the ordinary individual that the metric units operate with greater ease than English units.

137 centimeters = 13.7 decimeters = 1.37 meters
137 inches = 11 5/12 feet = 3 29/36 yards

The third difference observed between the two systems of measurement will be the terminology. In the metric system the three words, *meter, liter,* and *gram* are the basic terms. In addition there are six prefixes, three for multiples and three for decimal parts. The three multiples are the Greek terms *deka, hecto,* and *kilo,* meaning "ten," "one hundred," and "one thousand" respectively. The three prefixes for decimal parts are *deci-* (one-tenth), *centi-* (one-hundredth), and *milli-* (one-thousandth). The English system is lacking in this respect. For instance, the linear units—the inch, foot, yard, rod, and mile—do not indicate the part that one unit is of any other unit. The terminology is difficult.

The fourth difference is the interrelation between the units. In the metric system the basic units are related to each other, a fact which makes for economy in computation. In the English system there is no such relationship. Economy of computation is illustrated by the following example:

English system—What is the weight of an iron bar 4 inches by 4 inches by 8 feet? The specific gravity of iron is 7.86.

$$\text{Solution:}\quad \frac{4 \times 4 \times 8 \times 62.5 \times 7.86}{12 \times 12} = 436\ 2/3 \text{ pounds}$$

Metric system—What is the weight of an iron bar 4 centimeters by 4 centimeters by 8 meters? The specific gravity of iron is 7.86.

$$\text{Solution:}\quad \frac{4 \times 4 \times 8 \times 100 \times 7.86}{1{,}000} = 100.608 \text{ kilograms}$$

STEPS IN TEACHING THE METRIC SYSTEM

Teaching the metric system to prospective teachers involves the following steps:

1. Securing an inventory of the knowledge, concepts, and skills the students have. This makes for economy in both teaching and learning, since it indicates what needs to be taught as well as what is sufficiently well known.
2. Gaining a knowledge of the early history of measurement. In this connection, a definite need for a uniform system of measurement between those countries bound together by commercial interests will be understood and appreciated.
3. Becoming familiar with the metric system of measurement, its development and growth. Clear concepts of the basic units should be obtained by bringing these units to the class for study and use.
4. Understanding the ease of operation with metric units and

the economy effected by their use. This economy has previously been illustrated.

5. Developing sufficient skill in the use of metric units to serve one's needs. This skill is best obtained by using metric units in estimating and measuring distances, areas, volumes, weights, and capacities. Problems to be solved should be given in metric units, and computations should be kept within the metric system.

SUGGESTED EXERCISES FOR STUDENTS

Purpose: To become meter- and gram-conscious.

EXERCISE I

1. Estimate the length of the classroom in meters and hundredths.
2. Measure the length to the nearest centimeter.
3. Write this length in meters.
4. Estimate the width of the classroom. (Better results should be obtained than for No. 1.)
5. Measure the width to the nearest centimeter.
6. Express this width in meters.
7. Compute the area of the floor. (Round the answer to the nearest tenth of a square meter.)
8. Estimate the height of the classroom to the nearest centimeter.
9. Express this in meters.
10. Find the volume of the room. (Round the result to the nearest whole cubic meter.)

EXERCISE II

1. The better to become centimeter-conscious, estimate your height directly in centimeters. Do not convert inches to centimeters. Write your estimate on paper.
2. With meter stick and chalk at a doorpost measure your height in centimeters.
3. Compute your per cent of error.
4. Improve upon this per cent of error by estimating the height of your instructor in centimeters.

EXERCISE III

1. Handle and pass a large book between you and estimate its weight in grams. Do not announce your estimate, but write it down.
2. Have the book weighed on a metric scale.
3. Compute your per cent of error. Compare it with the per cent of error in the centimeter estimates.
4. Improve upon your per cent of error by handling and estimating the weight of another book or object.

EXERCISE IV

Study a teaching unit on the metric system for the elementary school, such as the preceding article, pages 267-283. Work all the examples there, including sets B and A.

OUTCOMES OF A STUDY OF THE METRIC SYSTEM

1. A better understanding of this system of measurement.
2. Ability to measure and to compute with metric units.
3. Appreciation of the need for a uniform system of measurement throughout the world.
4. Appreciation of the relationship between units of measure in the metric system, making operations in the metric system easier than operations in the English system.
5. Appreciation of the economy effected through the use of metric units.
6. Greater skill in the use of metric units.

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Appendix

RELATIONSHIPS BETWEEN THE ENGLISH AND METRIC WEIGHTS AND MEASURES

1. Relationship Between the Inch and Millimeter

R. E. HANSEN

AMERICAN industry has generally followed the English system of weights and measures, including adoption of the inch, foot, and yard as units of length. In 1866 an act of Congress legalized the use of the meter, thus giving recognition to the growing importance of the metric system all over the world. This act of 1866 defined the relationship between the two systems on the basis of 1 meter's equaling 39.37 inches. This ratio was probably not intended to be more accurate than the number of figures given, though it was later considered as defining the United States inch.

In 1889 the International Bureau of Weights and Measures prepared a number of platinum-iridium meter bars and determined with great exactness the length of each. One bar, No. 6, was adopted as the International Prototype, its length being considered exactly 1 meter. Other bars, calibrated in terms of the International Prototype, were distributed to a number of countries, two being sent to Washington. Congress in 1893 therefore accepted the International Prototype as the primary standard and one of the two similar bars in Washington as the National Standard, retaining the relationship of 39.37 inches to 1 meter. The National Standard has been sent to Paris since 1889 for comparison with the International Prototype, and no change in relative lengths has been detected.

Meanwhile Great Britain has employed a bronze bar as a national standard for the yard. The bar was made in 1845; comparison with the meter bar in 1895 gave its length as 914.3992 millimeters. This value was adopted as official by an act of Parliament. Later comparisons showed a change in the ratio to 914.3984 millimeters; the official conversion value, however, has not been changed.

Developments in spectroscopy make it possible to define length in terms of wave lengths of light. This has the advantage of providing a primary standard simultaneously available in many different places and not subject to destruction or alteration. One meter equal to 1,553,164.13 wave lengths of red cadmium radiation has gained wide recognition and is used by the International Astronomical Union. The present United States yard is equal to 1,420,216.12 wave lengths, and the British yard is equal to 1,420,212.03 wave lengths.

A proposal to adopt a conversion factor of 25.4 millimeters as equal to 1 inch was made in 1926 by a conference of representatives of standardizing bodies of eighteen countries, including the American Standards Association and the British Empire Standards Association. The practice had already been widely adopted on the Continent by engineers, and in the United States by manufacturers of mechanical screw-thread cutting devices and ruling scales.

In 1930 the British Standards Institute adopted 25.4 as a national standard conversion ratio. Two years later, at a conference of eighteen industrial bodies arranged at the request of the Ford Motor Company, it was recommended that the same standard be adopted for the United States. Those present included P. G. Agnew of the American Standards Association, L. J. Briggs and H. W. Bearce of the National Bureau of Standards, representatives of General Electric, American Telephone and Telegraph, Bell Telephone Laboratories, Browne & Sharpe, Bausch & Lomb, Western Electric, American Institute of Electrical Engineers, American Society of Mechanical Engineers, American Society of Swedish Engineers, Gage Manufacturers' Association, Metal Cutting Institute, National Electrical Manufacturers' Association, National Machine Tool Builder's Association, Society of Automotive Engineers, Manufacturers' Standardization Society of Valve and Fittings Industry, and the Navy Department's Bureau of Construction and Repair. The proposal was taken up and adopted by the American Standards Association on March 13, 1933. The standard so adopted, however, is purely a conversion factor and does not state what the primary standard shall be.

A bill drawn up and submitted to Congress in 1937 contained the following provisions:[1]

1. The meter, defined as the distance between two lines on the International Prototype Meter bar under specified conditions (temperature, pressure, and means of support), shall be a legal unit of length.

2. The United States inch, defined as 0.0254 meters, shall be a legal unit of length.

3. The United States primary standard shall be Meter No. 27, whose length shall be accepted as certified by the International Bureau of

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[1] Editor's note: This bill was not passed.

Weights and Measures; an alternative standard shall be the wave length of red radiation from cadmium, which may be converted to other units as below:

a. 1 wave length of red radiation from cadmium equals 6,438.4696 $\times 10^{10}$ meter.

b. 1 meter equals 1,553,164.13 wave lengths.

c. 1 inch equals 39,450.369 wave lengths.

System	Inches in 1 Meter	Millimeters Inch	Millimeters Yard	Wave Lengths of Cadmium Per Inch	Wave Lengths of Cadmium Per Yard
Present U. S.	39.37000	25.40005	914.40183	39,450.448	1,420,216.12
Proposed U. S.*	39.37008	25.40000	914.40000	39,450.369	1,420,213.28
Recent British	39.37015	25.39996	914.3984	39,450.305	1,420,210.93

* National Bureau of Standards.

2. Convenient Ways to Use Equivalent Tables[*]

A QUANTITY can usually be expressed as a whole number if the right metric weight or measure is selected. Even when a fraction is needed to express the metric equivalent of another weight or measure, one or two figures to the right of the decimal point generally give sufficient accuracy. Equivalents such as those in the tables here given should be used only to the required degree of accuracy. For example, as may be seen on page 302, 4 inches equal about 10 centimeters; if greater accuracy is desired, 10.2 centimeters or 102 millimeters may be taken.

The equivalent for a quantity greater or less than those given in the tables may be found in the following ways:

1. By multiplying or dividing by 10 or a multiple of 10. This may be done by merely changing the position of the decimal point (referring to page 302, the equivalent of 7 yards is 6.40 meters, so the equivalent of 700 yards is 640 meters).
2. By using the equivalents of its component parts (from page 302, 5 feet 8 1/2 inches = 152.4 centimeters + 20.3 centimeters + 1.3 centimeters = 174 centimeters).
3. By multiplying by the conversion factor required, which is opposite figure 1 in each column (from page 303, 65 kilograms × 2.2 = 143 avoirdupois pounds).

The tables in this section are based upon the United States equivalents, which, except for measures of capacity, are practically the same as the British. These exact figures are given below:

39.370000 United States inches = 1 meter
39.370113 British inches = 1 meter
0.2641776 United States gallon = 1 liter
0.2199753 British imperial gallon = 1 liter
1 United States avoirdupois pound = 0.4535924277 kilogram
1 British avoirdupois pound = 0.4535924300 kilogram

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[*] Reprinted from *Metric Weights and Measures*, Third Edition, the Metric Association, New York, 1919, by permission of the Association.

TABLE I

SUMMARY OF RELATIONSHIPS BETWEEN METRIC AND OTHER WEIGHTS AND MEASURES
(Equivalents in Nearest Thousandths)

LENGTH

1 centimeter = 0.394 inch
1 meter = 3.281 feet
1 meter = 1.094 yards
1 kilometer = 0.621 statute mile
1 kilometer = 0.540 nautical mile

1 inch = 2.540 centimeters
1 foot = 0.305 meter
1 yard = 0.914 meter
1 statute mile = 1.609 kilometers
1 nautical mile = 1.853 kilometers

CAPACITY

1 milliliter = 0.271 U. S. fluid drachm
1 milliliter = 0.034 U. S. fluid ounce
1 liter = 1.057 U. S. liquid quarts
1 liter = 0.908 U. S. dry quart
1 liter = 0.264 U. S. gallon

1 U. S. fluid drachm = 3.697 milliliters
1 U. S. fluid ounce = 29.573 milliliters
1 U. S. liquid quart = 0.946 liter
1 U. S. dry quart = 1.101 liters
1 U. S. gallon = 3.785 liters

1 milliliter = 0.282 British fluid drachm
1 milliliter = 0.035 British fluid ounce
1 liter = 0.880 British liquid quart
1 liter = 0.220 British imperial gallon

1 British fluid drachm = 3.552 milliliters
1 British fluid ounce = 28.412 milliliters
1 British liquid quart = 1.136 liters
1 British imperial gallon = 4.546 liters

WEIGHT

1 gram = 15.432 grains
1 gram = 0.643 pennyweight
1 gram = 0.772 apothecaries' scruple
1 gram = 0.257 apothecaries' drachm
1 gram = 0.035 avoirdupois ounce
1 gram = 0.032 troy ounce
1 kilogram = 2.205 avoirdupois pounds
1 kilogram = 2.679 troy pounds
1 metric ton = 0.984 gross or long ton
1 metric ton = 1.102 short or net tons

1 grain = 0.065 gram
1 pennyweight = 1.555 grams
1 apothecaries' scruple = 1.296 grams
1 apothecaries' drachm = 3.888 grams
1 avoirdupois ounce = 28.350 grams
1 troy ounce = 31.103 grams
1 avoirdupois pound = 0.454 kilogram
1 troy pound = 0.373 kilogram
1 gross or long ton = 1.016 metric tons
1 short or net ton = 0.907 metric ton

TABLE II

Metric-English Equivalents

LENGTH

Millimeters		*U. S. Inches*	*Centimeters*		*U. S. Inches*	*Meters*		*U. S. Feet*	*Meters*		*U. S. Yards*	*Kilometers*		*U. S. Miles*
1	=	0.03937	1	=	0.3937	1	=	3.28083	1	=	1.093611	1	=	0.62137
2	=	0.07874	2	=	0.7874	2	=	6.56167	2	=	2.187222	2	=	1.24274
3	=	0.11811	3	=	1.1811	3	=	9.84250	3	=	3.280833	3	=	1.86411
4	=	0.15748	4	=	1.5748	4	=	13.12333	4	=	4.374444	4	=	2.48548
5	=	0.19685	5	=	1.9685	5	=	16.40417	5	=	5.468056	5	=	3.10685
6	=	0.23622	6	=	2.3622	6	=	19.68500	6	=	6.561667	6	=	3.72822
7	=	0.27559	7	=	2.7559	7	=	22.96583	7	=	7.655278	7	=	4.34959
8	=	0.31496	8	=	3.1496	8	=	26.24667	8	=	8.748889	8	=	4.97096
9	=	0.35433	9	=	3.5433	9	=	29.52750	9	=	9.842500	9	=	5.59233

U. S. Inches		*Millimeters*	*U. S. Inches*		*Centimeters*	*U. S. Feet*		*Meters*	*U. S. Yards*		*Meters*	*U. S. Miles*		*Kilometers*
1	=	25.4001	1	=	2.54001	1	=	0.304801	1	=	0.914402	1	=	1.60935
2	=	50.8001	2	=	5.08001	2	=	0.609601	2	=	1.828804	2	=	3.21869
3	=	76.2002	3	=	7.62002	3	=	0.914402	3	=	2.743205	3	=	4.82804
4	=	101.6002	4	=	10.16002	4	=	1.219202	4	=	3.657607	4	=	6.43739
5	=	127.0003	5	=	12.70003	5	=	1.524003	5	=	4.572009	5	=	8.04674
6	=	152.4003	6	=	15.24003	6	=	1.828804	6	=	5.486411	6	=	9.65608
7	=	177.8004	7	=	17.78004	7	=	2.133604	7	=	6.400813	7	=	11.26543
8	=	203.2004	8	=	20.32004	8	=	2.438405	8	=	7.315215	8	=	12.87478
9	=	228.6005	9	=	22.86005	9	=	2.743205	9	=	8.229616	9	=	14.48412

CAPACITY

Milliliters		*U. S. Minims*	*Milliliters*		*U. S. Fluid Drachms*	*Milliliters*		*U. S. Fluid Ounces*	*Liters*		*U. S. Liquid Quarts*	*Liters*		*U. S. Gallons*	*Hectoliters*		*U. S. Bushels*
1	=	16.23	1	=	0.271	1	=	0.0338	1	=	1.057	1	=	0.2642	1	=	2.838
2	=	32.46	2	=	0.541	2	=	0.0676	2	=	2.113	2	=	0.5284	2	=	5.676
3	=	48.69	3	=	0.812	3	=	0.1014	3	=	3.170	3	=	0.7925	3	=	8.514
4	=	64.92	4	=	1.082	4	=	0.1353	4	=	4.227	4	=	1.0567	4	=	11.351
5	=	81.16	5	=	1.353	5	=	0.1691	5	=	5.284	5	=	1.3209	5	=	14.189
6	=	97.39	6	=	1.623	6	=	0.2029	6	=	6.340	6	=	1.5851	6	=	17.027
7	=	113.62	7	=	1.894	7	=	0.2367	7	=	7.397	7	=	1.8492	7	=	19.865
8	=	129.85	8	=	2.164	8	=	0.2705	8	=	8.454	8	=	2.1134	8	=	22.703
9	=	146.08	9	=	2.435	9	=	0.3043	9	=	9.510	9	=	2.3776	9	=	25.540

U. S. Minims		*Milliliters*	*U. S. Fluid Drachms*		*Milliliters*	*U. S. Fluid Ounces*		*Milliliters*	*U. S. Liquid Quarts*		*Liters*	*U. S. Gallons*		*Liters*	*U. S. Bushels*		*Hectoliters*
1	=	0.062	1	=	3.70	1	=	29.57	1	=	0.946	1	=	3.785	1	=	0.3524
2	=	0.123	2	=	7.39	2	=	59.15	2	=	1.893	2	=	7.571	2	=	0.7048
3	=	0.185	3	=	11.09	3	=	88.72	3	=	2.839	3	=	11.356	3	=	1.0572
4	=	0.246	4	=	14.79	4	=	118.29	4	=	3.785	4	=	15.141	4	=	1.4095
5	=	0.308	5	=	18.48	5	=	147.87	5	=	4.732	5	=	18.927	5	=	1.7619
6	=	0.370	6	=	22.18	6	=	177.44	6	=	5.678	6	=	22.712	6	=	2.1143
7	=	0.431	7	=	25.88	7	=	207.01	7	=	6.624	7	=	26.497	7	=	2.4667
8	=	0.493	8	=	29.57	8	=	236.58	8	=	7.571	8	=	30.283	8	=	2.8191
9	=	0.554	9	=	33.27	9	=	266.16	9	=	8.517	9	=	34.068	9	=	3.1715

TABLE II (*Continued*)

WEIGHT

Grams	*U. S. Grains*	*Grams*	*U. S. Avoirdupois Ounces*	*Grams*	*U. S. Troy Ounces*	*Kilograms*	*U. S. Avoirdupois Pounds*	*Metric Tons*	*U. S. Short Tons*
1	= 15.4324	1	= 0.03527	1	= 0.03215	1	= 2.20462	1	= 1.10231
2	= 30.8647	2	= 0.07055	2	= 0.06430	2	= 4.40924	2	= 2.20462
3	= 46.2971	3	= 0.10582	3	= 0.09645	3	= 6.61387	3	= 3.30693
4	= 61.7294	4	= 0.14110	4	= 0.12860	4	= 8.81849	4	= 4.40924
5	= 77.1618	5	= 0.17637	5	= 0.16075	5	= 11.02311	5	= 5.51156
6	= 92.5941	6	= 0.21164	6	= 0.19290	6	= 13.22773	6	= 6.61387
7	= 108.0265	7	= 0.24692	7	= 0.22506	7	= 15.43236	7	= 7.71618
8	= 123.4589	8	= 0.28219	8	= 0.25721	8	= 17.63698	8	= 8.81849
9	= 138.8912	9	= 0.31747	9	= 0.28936	9	= 19.84160	9	= 9.92080

U. S. Grains	*Grams*	*U. S. Avoirdupois Ounces*	*Grams*	*U. S. Troy Ounces*	*Grams*	*U. S. Avoirdupois Pounds*	*Kilograms*	*U. S. Short Tons*	*Metric Tons*
1	= 0.06480	1	= 28.3495	1	= 31.1035	1	= 0.45359	1	= 0.90718
2	= 0.12960	2	= 56.6991	2	= 62.2070	2	= 0.90718	2	= 1.81437
3	= 0.19440	3	= 85.0486	3	= 93.3104	3	= 1.36078	3	= 2.72155
4	= 0.25920	4	= 113.3981	4	= 124.4139	4	= 1.81437	4	= 3.62874
5	= 0.32399	5	= 141.7476	5	= 155.5174	5	= 2.26796	5	= 4.53592
6	= 0.38879	6	= 170.0972	6	= 186.6209	6	= 2.72155	6	= 5.44311
7	= 0.45359	7	= 198.4467	7	= 217.7244	7	= 3.17515	7	= 6.35029
8	= 0.51839	8	= 226.7962	8	= 248.8278	8	= 3.62874	8	= 7.25748
9	= 0.58319	9	= 255.1457	9	= 279.9313	9	= 4.08233	9	= 8.16466

TABLE III

METRIC EQUIVALENTS FOR DOUBLE MARKING ON LABELS

Example: 12 U. S. avoirdupois ounces = 340 grams 12 U. S. fluid ounces = 355 milliliters

U. S. Avoirdupois Pounds and Ounces to Grams

Avoirdupois Ounces	*Grams*	*Avoirdupois Ounces*	*Grams*	*Pounds*	*Ounces*	*Grams*
¼	= 7	8	= 227	1		= 454
½	= 14	8½	= 241	1	1	= 482
¾	= 21	9	= 255	1	2	= 511
1	= 28	9½	= 269	1	3	= 539
1½	= 43	10	= 283	1	4	= 567
2	= 57	10½	= 298	1	5	= 595
2½	= 71	11	= 312	1	6	= 624
3	= 85	11½	= 326	1	7	= 652
3½	= 99	12	= 340	1	8	= 680
4	= 113	12½	= 354	1	9	= 709
4½	= 128	13	= 369	1	10	= 737
5	= 142	13½	= 383	1	11	= 765
5½	= 156	14	= 397	1	12	= 794
6	= 170	14½	= 411	1	13	= 823
6½	= 184	15	= 425	1	14	= 851
7	= 198	15½	= 439	1	15	= 879
7½	= 213	16	= 454	2		= 907
				3		= 1,361

U. S. Pints and Fluid Ounces to Milliliters (or Cubic Centimeters)

Fluid Ounces	*Milliliters*	*Pints*	*Ounces*	*Milliliters*
1	= 30	1	1	= 503
2	= 59	1	2	= 532
3	= 89	1	3	= 562
4 (½ cup)	= 118	1	4	= 591
5	= 148	1	5	= 621
6	= 178	1	6	= 650
7	= 207	1	7	= 680
8 (1 cup)	= 237	1	8	= 710
9	= 266	1	9	= 739
10	= 296	1	10	= 769
11	= 325	1	11	= 798
12	= 355	1	12	= 828
13	= 384	1	13	= 857
14	= 414	1	14	= 887
15	= 443	1	15	= 916
16 (1 pt.)	= 473	2 (1 qt.)		= 946
		1 gal.		= 3,785
				= 3.785 l